DOCUMENT RESUME

ED 279 827 CE 046 488

TITLE	Aviation Maintenance Technology. General. G105 Aviation Electricity and Electronics. Instructor Material.
INSTITUTION	Oklahoma State Board of Vocational and Technical Education, Stillwater. Curriculum and Instructional Materials Center.; Tulsa County Schools, Okla.
PUB DATE	85
NOTE	416p.; For related documents, see CE 046 483-487.
AVAILABLE FROM	Curriculum and Instructional Materials Center, Oklahoma State Board of Vocational and Technical Education, 1500 West Seventh Avenue, Stillwater, OK 74074 (Order No. TI 1204: in state--$22.00, out of state--$55.00).
PUB TYPE	Guides - Classroom Use - Guides (For Teachers) (052)
EDRS PRICE	MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	*Aviation Mechanics; *Aviation Technology; Classroom Techniques; *Electricity; *Electronics; Job Skills; Learning Activities; Learning Modules; Postsecondary Education; Skill Development; Teaching Methods; Test Items; Transparencies; Units of Study; Vocational Education
IDENTIFIERS	Oklahoma

ABSTRACT

These instructor materials for an aviation maintenance technology course contain five instructional modules. The modules cover the following topics: determining the relationship of voltage, current, resistance, and power in electrical circuits; computing and measuring capacitance and inductance; measuring voltage, current, resistance, and continuity; reading and interpreting electrical circuit diagrams; and inspecting and servicing aircraft batteries. Each module contains some or all of these nine basic components--a module introduction and objective, performance objectives, instructor's module implementation guide, technical information supplements, workbook supplements, project guides, theory test, answers to theory test and workbook supplements, and a practical test. These materials were developed through a cooperative effort of airframe and powerplant mechanics, general aviation industry representatives, Federal Aviation Administration representatives, and vocational educators in Oklahoma to provide a comprehensive program in aviation maintenance technology. (KC)

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AVIATION MAINTENANCE TECHNOLOGY

GENERAL

G105 AVIATION ELECTRICITY AND ELECTRONICS

INSTRUCTOR MATERIAL

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MODULE OF INSTRUCTION
FOR
AVIATION MAINTENANCE TECHNOLCOGY

GENERAL
G105 AVIATION ELECTRICITY AND ELECTRONICS
DETERMINE THE RELATIONSHIP OF VOLTAGE, CURRENT, RESISTANCE, AND POWER IN ELECTRICAL CIRCUITS
G105-A

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INTRODUCTION

Airplanes once had a couple of small AC generators with step-up magnetos to provide ignition, a relatively simple DC generator, and a battery to provide light and mechanical power. Today almost all aircraft have relatively complex electrical systems and electronically controlled components. Alternating current is being used more as power requirements go up and ground power units become increasingly available. As an aviation maintenance technician, it will be your responsibility to maintain these complex systems.

MODULE OBJECTIVE

After completion of this module, you will be able to explain the principles of DC electricity. You will also be able to solve problems using the relationship between voltage, current, resistance, and power in series, parallel, and series-parallel circuits. You will demonstrate this knowledge by completing the procedures outlined in the workbook supplements and by scoring a minimum of 85 percent on the module theory test.

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SPECIFIC OBJECTIVES

After completion of this module, you will be able to

1.	Match terms related to electron theory to their correct definitions. (1)	Technical Supplement #1	
2.	Label the parts of an atom. (2)	EA-ITP-G EA-ITP-GW	2:II:2 2:1
3.	Describe the electron flow in a conductor. (2)	EA-ITP-G EA-ITP-GW	2:II:3-4 2:1
4.	List the five units of electrical measurement. (1)	EA-ITP-G EA-ITP-GW	2:II:4-5 2:2
5.	Match metric prefixes to their correct multipliers. (1)	EA-ITP-G EA-ITP-GW	2:II:5-6 2:2
6.	Multiply and divide numbers using the powers of ten. (3)	EA-ITP-G EA-ITP-GW	I:V:10-11 1:6-7
7.	Discuss the relationship between static electricity and friction for an aircraft. (2)	EA-ITP-G EA-ITP-GW	2:III:7-9 2:3
8.	Match terms related to magnets and electromagnets to their correct definitions. (1)	Technical Supplement #2 EA-ITP-G EA-ITP-GW	 2:V:15-16 2:3
9.	Describe the magnetic lines of force of a permanent magnet. (1)	EA-ITP-G EA-ITP-GW	2:IV:10-12 2:3-4
10.	Select true statements related to electromagnets. (1)	EA-ITP-G EA-ITP-GW	2:V:13-15 2:4-5
11.	Match terms related to DC electricity to their correct definitions. (1)	Technical Supplement #3	
12.	List the five sources of electrical energy. (2)	EA-ITP-G EA-ITP-GW	2:VI:17-18 2:5
13.	State the relationship between voltage, current, and resistance using Ohm's law. (2)	EA-ITP-G EA-ITP-GW	2:VII:19-20 2:5-7

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14. Match terms related to circuit elements to their correct definitions. (1)	Technical Supplement #4	
15. List the three elements of a simple electrical circuit. (1)	EA-ITP-G	2:VIII:21
16. Explain the physical characteristics that affect the resistance of a conductor. (1)	EA-ITP-G EA-ITP-GW	2:VIII:21-22 2:7
17. List the three main types of switches used in a circuit as control devices. (1)	EA-ITP-G EA-ITP-GW	2:VIII:23-24 2:8
18. List the two main types of circuit protective devices. (1)	EA-ITP-G EA-ITP-GW	2:VIII:24-25 2:8-9
19. List the two types of circuit resistors. (1)	EA-ITP-G EA-ITP-GW	2:VIII:25-27 2:9
20. Match terms related to circuit arrangements to their correct definitions. (1)	Technical Supplement #5	
21. Define the three types of circuits. (2)	EA-ITP-G	2:IX-28-32
22. State the principle of Kirchhoff's voltage law. (1)	EA-ITP-G	2:IX:29
23. State the principle of Kirchhoff's current law. (1)	EA-ITP-G	2:IX:30
24. Identify basic electrical symbols related to DC electricity. (1)	Technical Supplement #6	
25. Solve problems using the relationship between current, voltage, and resistance in a series circuit. (3)	EA-ITP-GW Workbook Supplements #1-#7	2:9-14
26. Compute the power dissipated in a resistive circuit. (3)	EA-ITP-G EA-ITP-GW Workbook Supplement #8	2:IX:29-30 2:12
27. Distinguish between the characteristics of a series circuit and a parallel circuit. (3)	EA-ITP-G	2:IX:30-31

SPECIFIC OBJECTIVES

28. Solve problems using the relationship between current, voltage, and resistance in a parallel circuit. (3)	EA-ITP-GW 2:10-11 Workbook Supplements #9-#10
29. Solve problems using the relationship between current, voltage, resistance, and power in a parallel circuit. (3)	EA-ITP-G 2:IX:32 EA-ITP-GW 2:12 Workbook Supplements #11-#14
30. Solve problems using the relationship between current, voltage, resistance, and power in a series-parallel circuit. (3)	EA-ITP-G 2:IX:33-37 EA-ITP-GW 2:13 Workbook Supplements #15-#25

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INSTRUCTOR'S MODULE IMPLEMENTATION GUIDE

I. Order materials to supplement module--Videotapes:

A. *Electron Theory*, ITP-G2, Program 1.

B. *Sources of Electrical Energy*, ITP-G2, Program 2.

C. *Units of Electrical Measurement*, ITP-G2, Program 3.

D. *DC Circuit Elements*, ITP-G2, Program 5.

E. *DC Circuit Arrangement*, ITP-G2, Program 5.

(NOTE: These materials are available from Aviation Maintenance Publishers, Inc., P.O. Box 36, 1000 College View Drive, Riverton, Wyoming 82501.)

II. Implementation Suggestions

(NOTE: Have students read all material related to Specific Objectives. Much of this reading can be done as homework assignments.)

Estimated Teaching Time		Theory	Lab
Objective 1	Explain the terms used in electron theory. Have students read Technical Information Supplement #1.		
Objective 2	Explain the parts of an atom. Show Transparency Master #1. Have students complete EA-ITP-GW 2, page 1.		
Objective 3	Explain electron flow in a conductor. Explain the relationship between electron flow and current flow. Show Transparency Master #2 and show videotape ITP-G2, Program 1, *Electron Theory*. Have students complete EA-ITP-GW 2, page 1.		
Objective 4	Explain the five units of electrical measurement. Show Transparency Masters #3-#5. Have students complete EA-ITP-GW 2, page 2. Assist students as necessary.		

Estimated Teaching Time		Theory	Lab
Objective 5	Explain how to read the metric prefixes used to abbreviate numbers. Show Transparency Master #6. Have students complete EA-ITP-GW 2, page 2. Assist students as necessary.		
Objective 6	Demonstrate procedures for multiplication and division of numbers using the powers of ten. Have students complete EA-ITP-GW 1, pages 6-7. Assist students as necessary.		
Objective 7	Demonstrate the relationship between static electricity and friction. Explain how static wicks and bonding straps are used to control static electricity. Show Transparency Master #7. Have students complete EA-ITP-GW 2, page 3. Assist students as necessary.		
Objective 8	Explain the terms used to describe permanent magnets and electromagnets. Have students read Technical Information Supplement #2. Have students complete EA-ITP-GW 2, page 3. Assist students as necessary.		
Objective 9	Explain how the lines of magnetic flux flow in and around a permanent magnet. Show Transparency Masters #8 and #9. Have students complete EA-ITP-GW 2, pages 3-4. Assist students as necessary.		
Objective 10	Explain the left-hand rule relating to electron flow and lines of flux in determining the north pole of an electromagnet. Show Transparency Masters #10 and #11. Have students complete EA-ITP-GW, 2, pages 4-5. Assist students as necessary.		
Objective 11	Explain the terms used in basic DC electricity. Have students read Technical Information Supplement #3.		

INSTRUCTOR'S MODULE IMPLEMENTATION GUIDE

Estimated Teaching Time		Theory	Lab
Objective 12	Explain the five sources of electrical energy. Show Transparency Masters #12-#16. Show videotape ITP-G2, Program 2, Sources of Electrical Energy. Have students complete EA-ITP-GW 2, page 5. Assist students as necessary.		
Objective 13	Demonstrate the application of Ohm's law in an electrical circuit. Show Transparency Masters #17 and #18. Show videotape ITP-G2, Program 3, Units of Electrical Measurement. Have students complete EA-ITP-GW 2, pages 5-7. Assist students as necessary.		
Objective 14	Explain the terms used to describe circuit elements. Have students read Technical Information Supplement #4. Show videotape ITP-G2, Program 5, DC Circuit Elements.		
Objective 15	Demonstrate the three elements needed to complete a circuit. Use a drawing similar to Figure 8-1 in EA-ITP-G2, Section VIII, page 21, and show Transparency Master #19.		
Objective 16	Explain the physical characteristics of a conductor which affect its resistance. Explain resistivity and the effects of changing temperature. Have students compete EA-ITP-GW 2, page 7. Explain how the length and cross-sectional area will affect the resistance of a conductor. Assist students as as necessary.		
Objective 17	Explain the different types of switches that can be used in a circuit as control devices. Have students complete EA-ITP-GW 2, page 8. Assist students as necessary.		

Estimated Teaching Time		Theory	Lab
Objective 18	Explain the need for a protective device, such as a fuse or circuit breaker, in a circuit. Have students complete EA-ITP-GW 2, pages 8-9. Assist students as necessary.		
Objective 19	Explain that it is often necessary to control current flow in a circuit by varying voltage. Show how resistors of different types and sizes can be used to drop the voltage in a circuit. Have students complete EA-ITP-GW 2, page 9. Assist students as necessary.		
Objective 20	Explain the terms that will be used in different circuit arrangements. Have students read Technical Information Supplement #5. Show videotape ITP-G2, Program 5, DC Circuit Arrangement.		
Objective 21	Explain the types of circuits: series, parallel, and complex (also called series-parallel).		
Objective 22	Explain the principle of Kirchhoff's voltage law and how it helps us understand the action in a series circuit. Show Transparency Master #20		
Objective 23	Explain the principle of Kirchhoff's current law and how it helps us understand the behavior of a parallel circuit. Show Transparency Master #21.		
Objective 24	Describe the symbols used in a basic electrical circuit, using Technical Information Supplement #6.		
Objective 25	Explain the characteristics of series circuits, and how they will be used in measuring values in the circuit. Explain how to solve problems for current, voltage, and resistance in a series circuit. Have students complete EA-ITP-GW 2, pages 9-14 and Workbook Supplements #1-#7. Assist students as necessary.		

INSTRUCTOR'S MODULE IMPLEMENTATION GUIDE

Estimated Teaching Time		Theory	Lab
Objective 26	Explain how to compute power dissipated in a resistive circuit. Have students complete EA-ITP-GW 2, page 12 and Workbook Supplement #8. Assist students as necessary.		
Objective 27	Explain the characteristics of a parallel circuit, and how they will be used in measuring values in the circuit. Discuss how the characteristics of a parallel circuit are different from the characteristics of a series circuit.		
Objective 28	Explain how to solve for current, voltage, and resistance in a parallel circuit. Have students complete EA-ITP-GW 2, pages 10-11 and Workbook Supplements #9 and #10. Assist students as necessary.		
Objective 29	Explain how to solve problems in a parallel circuit to find current, voltage, resistance, and power. Have students complete EA-ITP-GW 2, page 12 and Workbook Supplements #11-#14. Assist students as necessary.		
Objective 30	Explain how to solve problems in a series-parallel circuit to find current, voltage, resistance, and power. Have students complete EA-ITP-GW 2, page 13 and Workbook Supplements #15-#25. Assist students as necessary.		

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TECHNICAL INFORMATION SUPPLEMENT #1 - Terms and Definitions: Electron Theory

A. Atom - Smallest particle of an element

B. Electron - Most basic particle of negative electricity

C. Proton - Positively charged particles in the nucleus of an atom

D. Nucleus - Center or core of an atom, consisting of positively charged protons and uncharged neutrons

E. Neutron - Uncharged particle in the nucleus of an atom

(NOTE: Mass of a neutron is essentially equal to that of a proton.)

F. Ion - Atom that has either gained or lost an electron

G. Positive ion - Atom with a shortage of electrons

H. Negative ion - Atom with an excess of electrons

I. Electron current flow - Flow of electrons from negative to positive in a circuit outside the source

J. Electron flow - Flow of electrons in a circuit

K. Molecule - Smallest particle of an element or compound that is capable of retaining the chemical identity

L. Compound - New entity formed by union of elements or parts

M. Element - Chemical substance that cannot be divided into simpler substances by chemical means

N. Free electrons - Electrons so loosely bound in the outer shells of some atoms that when an electromotive force is applied to the material, they are able to move from atom to atom

O. Kilo - Metric term meaning one thousand

P. Milli - Metric prefix meaning one one-thousandth

Q. Mega - Metric prefix meaning one million

R. Micro - Metric term meaning one millionth

S. Pulsating direct current - Direct current that changes from zero to maximum, and then back to zero

T. Direct current (DC) - Flow of electrons in one direction throughout a circuit

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TECHNICAL INFORMATION SUPPLEMENT #2 - Terms and Definitions: Magnets and Electromagnets

A. Magnetism - Ability to attract certain materials containing iron and to influence moving electrons

B. Magnetic field - Space around a magnet or conductor where magnetic flux is found

C. Magnet - Device or material that has the property of attracting or repelling other magnetic materials

D. Magnetic flux - Invisible lines of magnetic force that are assumed to exist between the poles of a magnet

E. Permeability - Ability of a material to accept and concentrate lines of magnetic flux

F. Permanent magnet - Ferrous metal or alloy of ferrous metals, usually containing nickel and cobalt, in which the magnetic domains are aligned, and tend to remain aligned

G. Lines of flux - Lines of magnetic force connecting the poles of a magnet

H. Electromagnetism - Magnetism developed by the magnetic field surrounding a current-carrying wire

I. Electromagnet - Magnet produced by electrical current flowing through a coil

(NOTE: The core is usually made of soft iron, which concentrates the lines of flux and intensifies the magnetic field.)

J. Conductor - Material whose outer ring electrons are loosely bonded, so that a relatively low voltage will cause a flow of these electrons

K. Magnetomotive force (MMF) - Magnetizing force, measured in gilberts or ampere-turns

L. Ampere-turn - Measure of magnetomotive force of an electromagnet; equivalent to the force produced when one ampere of current flows through one turn of the coil

M. Flux - Magnetic lines of force

N. Gauss - Measurement of flux density equal to one line of flux per square centimeter

O. Maxwell - One line of magnetic flux

P. Gilbert - Amount of magnetomotive force required to maintain one maxwell in a magnetic circuit having one unit of reluctance

(NOTE: One gilbert = $10/4\pi$ ampere-turns)

Q. Reluctance - Opposition to magnetic flux

(NOTE: Reluctance is the opposite of permeability.)

R. Residual magnetism - Magnetism that remains in the core of an electromagnet after the magnetizing current no longer flows in the coil

S. Retentivity - Ability of a material to retain its magnetic properties

T. Pole - Designation given to the ends of a magnet

U. Polarity - Property of an electrical device of having two different types of electrical charges

V. Ferromagnetic materials - Magnetic materials composed largely of iron

W. Coil - Conductor consisting of turns of wire in which the magnetic field around one turn cuts across the other turns, increasing the inductive effect of the wire

X. D'Arsonval meter movement - A pointer mounted on an electromagnet in the field of a permanent magnet

(NOTE: This is the most commonly used meter movement in DC measuring instruments. The amount of current in the coil determines the strength of the electromagnet, thus the amount of pointer deflection.)

Y. Electrodynamic damping - Diminishing of oscillations of the pointer of an electrical meter by the generation of electromagnetic fields in the frame of the moving coil

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TECHNICAL INFORMATION SUPPLEMENT #3 - Terms and Definitions: Direct Current Electricity

A. Ohm's law - Law which establishes the relationship between current, voltage, and resistance in an electrical circuit

(NOTE: Ohm's law states that the current in a circuit is directly proportional to the voltage causing it and inversely proportional to the resistance of the circuit.)

B. Watt (W) - Basic unit of electrical power

(NOTE: One ampere flowing under a pressure of one volt is equal to one watt. One watt equals 1/746 horsepower.)

C. Current (I) - Flow of electrons

(NOTE: Current is commonly called current flow. Current flow is measured in amperes.)

D. Ampere - One coulomb per second

E. Resistance (R) - Opposition to the flow of electrons offered by a device or material

F. Volt (V) - Unit of measure of electrical pressure; equivalent to the pressure required to force one ampere of current through one ohm of resistance

G. Electricity - Composed of electrons and protons that can be observed in the attracting and repelling of objects electrified by friction and in lightning and the aurora borealis

H. Voltage (E) - Force causing flow of electrons, measured in volts

I. Potential - Term for electrical pressure or voltage

J. Potential difference (pd) - Voltage existing between two terminals or two points of differing potential

K. Electromotive force (emf) - Force causing electrons to move through a conductor

(NOTE: The symbol E is used in calculations until the actual number of volts is determined.)

L. Ohm (Ω) - Unit of electrical opposition equal to the resistance of a circuit in which an electromotive force of one volt will maintain a current of one ampere

M. Horsepower (HP) - Standard unit of power used for mechanical measurement

(NOTE: One horsepower is equal to 33,000 foot-pounds of work done in one minute. Electrically, it is equal to 746 watts.)

N. Motor - Device that converts electrical energy into mechanical energy

O. Work - Product of force and the distance through which the force acts

P. Dielectric - Material that has very few free electrons

Q. Electrical short - Unintentional, low-resistance path to ground for electrical current without its passing through the electrical load

R. Energy - Capacity for doing work

S. Static electricity - Electrical charge which may be built up on a nonconductive surface by friction

T. Ground - Reference point for voltage measurement in an electrical circuit; to connect a part or component to the electrical ground

U. Bonding jumper - Wire or electrical connection used to electrically ground a component or structure to an airframe

V. Shielding - Metal covers placed around electric and electronic devices to prevent the intrusion of external electrostatic and electromagnetic fields

TECHNICAL INFORMATION SUPPLEMENT #4 - Terms and Definitions: Circuit Elements

A. Resistor - Electrical circuit element used to provide a voltage drop by dissipating some of the electrical energy in the form of heat

B. Generator - Mechanical device consisting of a conductor being turned within a magnetic field, used to produce electricity by electromagnetic induction

C. Battery - Device made up of a number of individual cells, used to store electricity by converting it into chemical energy

D. Circuit - Complete path in which electrical current flows

(NOTE: A circuit must contain a source of electrical energy, a load to absorb this energy, and conductors to carry the electron flow.)

E. Switch - Manually operated device that opens and closes an electrical circuit

F. Relay - Electrically operated remote switch whose contacts are closed or opened by a solenoid

G. Solenoid - Electromagnetic field and core necessary to open and close the contacts of the relay

H. Load - Energy-absorbing or energy-using device connected to a current

I. Fuse - Link of low-melting-point metal in an electrical circuit, which will melt and open the circuit when an excessive amount of current flows

J. Circuit breaker - Circuit-protecting device which opens the circuit in the case of excess current flow

(NOTE: A circuit breaker differs from a fuse in that a circuit breaker can be reset without having to be replaced.)

K. Brush - Device designed to provide an electrical contact between a stationary conductor and a rotating element

L. Bus bar - Electrical power distribution point to which several circuits may be connected

(NOTE: A bus bar is often a solid metal strip having a number of terminals installed on it.)

M. Capacitor - Device used to store electrical energy in the form of electrostatic fields

(NOTE: A capacitor is essentially two conductors separated by an insulator.)

N. Insulator - Material or device used to prevent passage of heat, electricity, or sound from one medium to another

O. Potentiometer - Variable resistor having both ends and its wiper in the circuit and used as a voltage divider; or instrument used for measuring differences in electrical potential by balancing the unknown voltage against a known variable voltage

P. Rheostat - Variable resistor having only two terminals

(NOTE: A rheostat is normally used in a circuit to drop voltage by dissipating some of the energy as heat.)

TECHNICAL INFORMATION SUPPLEMENT #5 - Terms and Definitions: Circuit Arrangements

A. Parallel circuits - Two or more complete circuits connected to the same two power terminals

B. Series circuit - Circuit in which there is only one path for electron flow from the source through the load back to the source

C. Open circuit - Electrical circuit that is not complete or continuous

D. Voltmeter - Electrical measuring instrument used to measure electrical pressure or voltage

E. Ohmmeter - Electrical measuring instrument used to measure resistance by the amount of current which flows when a known voltage is applied across the unknown resistance

F. Milliammeter - Electrical current measuring device calibrated to read in milliamperes

(NOTE: 1000 milliamperes = 1 ampere.)

G. Ammeter - Electrical measuring instrument used to measure electron flow in amperes

H. Ampere-hour - Measure of the capacity of a battery; equivalent to the product of the amount of current flow and the time in which this amount can flow

I. Megohmmeter - High-resistance measuring instrument incorporating a high-voltage DC generator in the instrument case

(NOTE: A megohmmeter measures high resistance with enough voltage to cause insulation breakdown if it has been weakened.)

J. Shunt - Accurately calibrated resistor placed in parallel with a meter movement for measuring current

(NOTE: Current flows through the shunt and produces a voltage drop proportional to the amount of current. The ammeter movement measures this voltage drop and displays it in amperes.)

K. Terminal - Connecting fitting attached to the end of a wire, battery, or other component

L. Terminal strip - Strip of insulating material containing terminal posts to which aircraft wiring is attached

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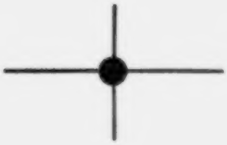
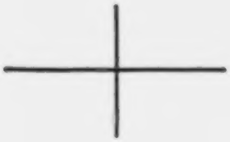
RESISTANCE, AND POWER IN ELECTRICAL CIRCUITS
G105-A

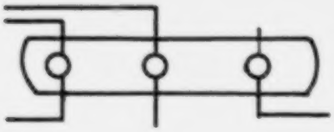
TECHNICAL INFORMATION SUPPLEMENT #6 - Basic DC Electrical Symbols



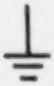
PERMANENT
CONNECTION



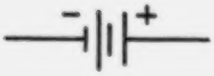
NO CONNECTION



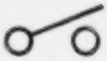
BUS



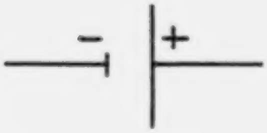
GROUND



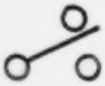
BATTERY



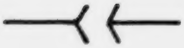
SPST SWITCH
(SINGLE-POLE, SINGLE THROW)



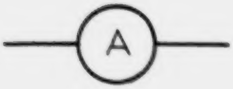
ONE CELL



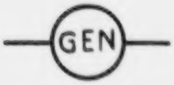
SPDT SWITCH
(SINGLE-POLE, DOUBLE THROW)



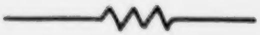
SINGLE CONDUCTOR CONNECTOR



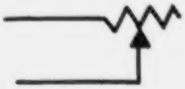
AMMETER



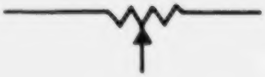
GENERATOR



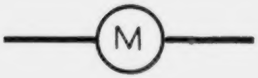
RESISTOR



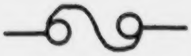
RHEOSTAT



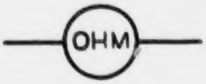
POTENTIOMETER



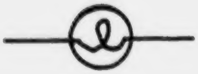
MOTOR



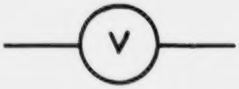
FUSE



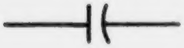
OHMMETER



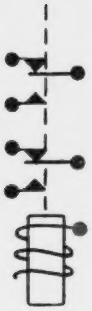
LAMP OR BULB



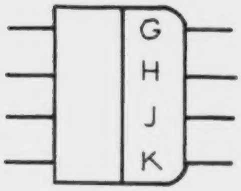
VOLTMETER



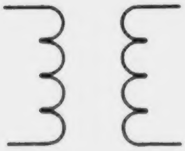
FIXED CAPACITOR



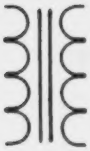
RELAY COIL
WITH CONTACTS



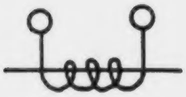
FOUR CONDUCTOR
CONNECTOR



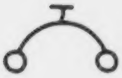
AIR CORE TRANSFORMER



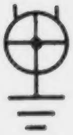
IRON CORE TRANSFORMER



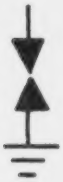
SOLENOID



CIRCUIT BREAKER

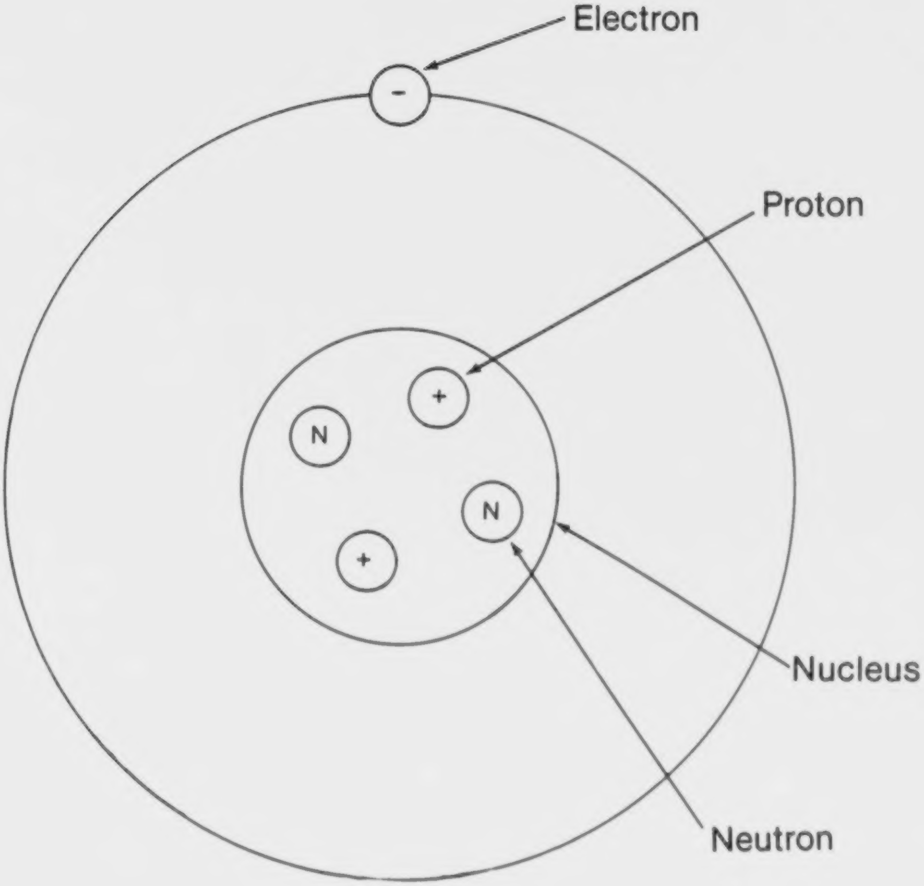


SPARK IGNITER

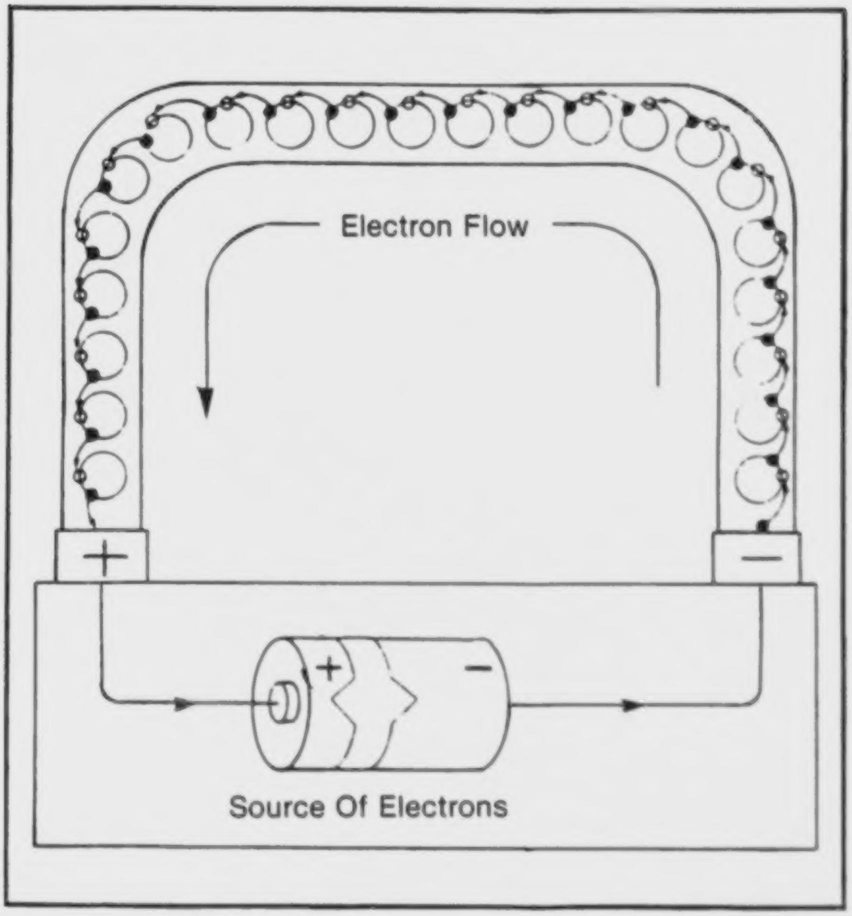


SPARK PLUG

The Atom and Its Particles


Electron
-
Proton
+
N
N
+
Nucleus
Neutron

Electron Flow


Electron Flow
+
−
+
−
Source Of Electrons

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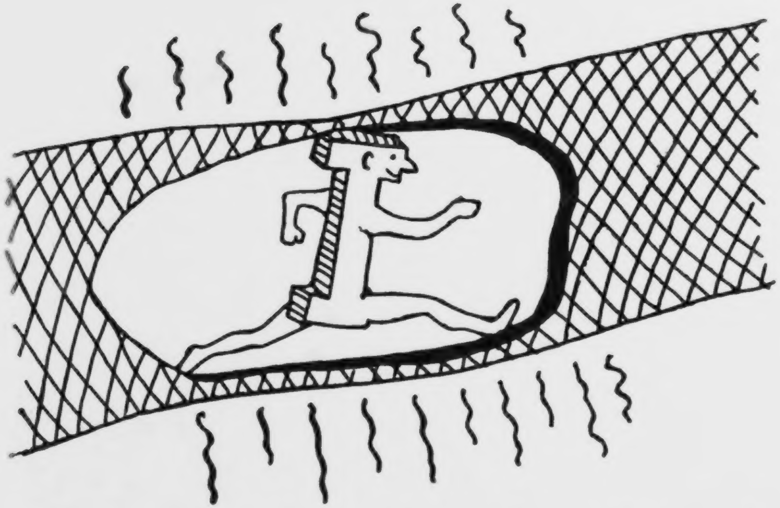
Current



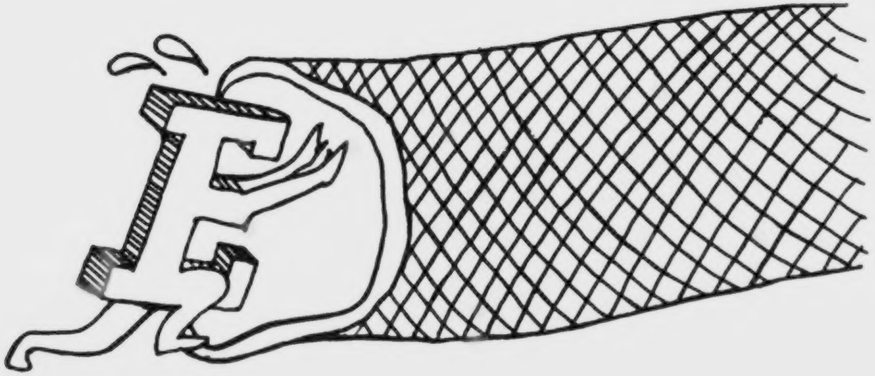
Current is the rate of flow of electrons

Definition: The rate of electron flow through a conductor is called current flow. A flow of 6.28×10^{18} electrons per second is called an ampere.

Symbol: I

Measured in: Amperes (1 ampere = one coulomb/second)
Instrument used to measure: Ammeter.
Symbol -ⓐ- or -Ⓘ- or -Ⓐ-

Voltage



Voltage is pressure, or electromotive force

Voltage makes electrons "want to move" — Symbol: E or V

Measured in: Volts — Symbol: V

Instrument used to measure: Voltmeter. Symbol V

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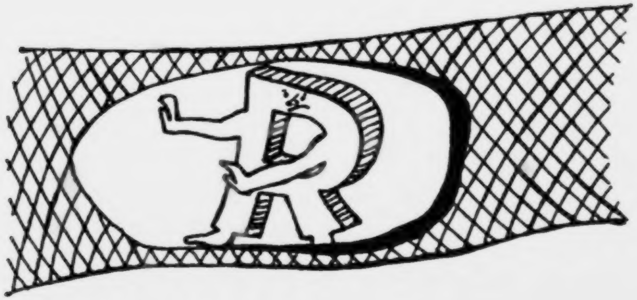
Resistance



Resistance is opposition
to current flow

Definition: Resistance can be said to be the internal friction involved in the passing of electrons through a wire.

Symbol: R

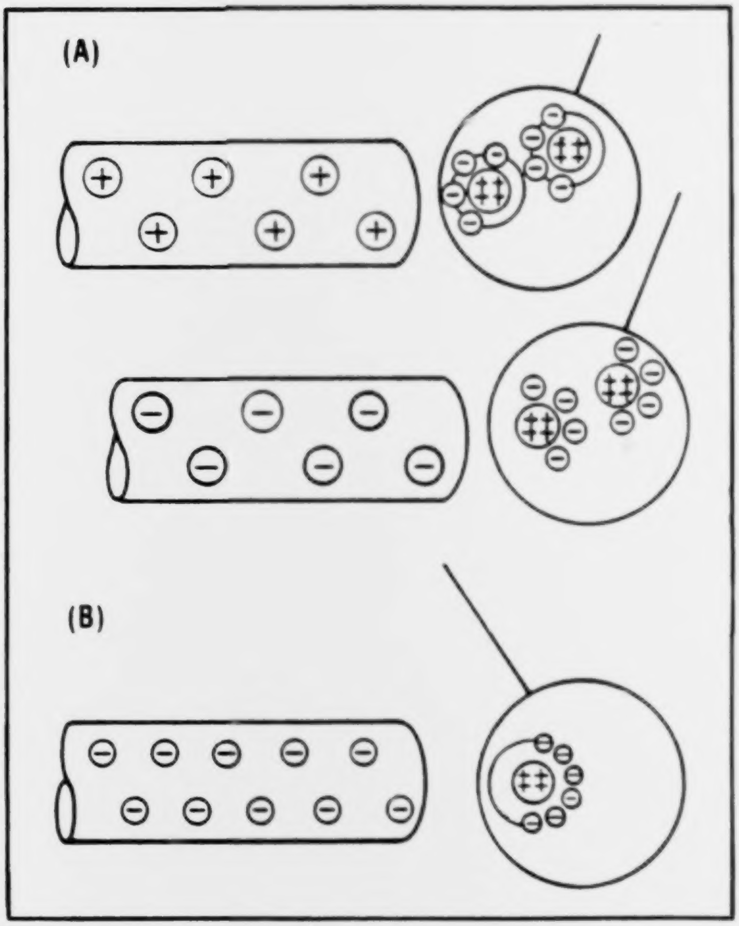
Measured in: Ohms — Symbol: Ω

Instrument used to measure: Ohmmeter. Symbol -(OHM)-

Metric Unit Prefixes

Prefix	Symbol	Power of 10	Numerical Value	
tera	t	10^{12}	trillion	1,000,000,000,000
		10^{11}	hundred-billion	100,000,000,000
		10^{10}	ten-billion	10,000,000,000
giga	g	10^{9}	billion	1,000,000,000
		10^{8}	hundred-million	100,000,000
		10^{7}	ten-million	10,000,000
mega	M	10^{6}	million	1,000,000
		10^{5}	hundred-thousand	100,000
myria	my	10^{4}	ten-thousand	10,000
kilo	k	10^{3}	thousand	1,000
hecto	h	10^{2}	hundred	100
deka	dk	10^{1}	ten	10
		10^{0}	one	1
deci	d	10^{-1}	tenth	.1
centi	c	10^{-2}	hundredth	.01
milli	m	10^{-3}	thousandth	.001
		10^{-4}	ten-thousandth	.000 1
		10^{-5}	hundred-thousandth	.000 01
micro	μ	10^{-6}	millionth	.000 001
		10^{-7}	ten-millionth	.000 000 01
		10^{-8}	hundred-millionth	.000 000 01
nano	n	10^{-9}	billionth	.000 000 001
		10^{-10}	ten-billionth	.000 000 000 1
		10^{-11}	hundred-billionth	.000 000 000 01
pico	p	10^{-12}	trillionth	.000 000 000 001
		10^{-13}	ten-trillionth	.000 000 000 000 1
		10^{-14}	hundred-trillionth	.000 000 000 000 01
femto	f	10^{-15}	quadrillionth	.000 000 000 000 001
		10^{-16}	ten-quadrillionth	.000 000 000 000 000 1
		10^{-17}	hundred-quadrillionth	.000 000 000 000 000 01
atto	a	10^{-18}	quintillionth	.000 000 000 000 000 001

Static Electricity



A — An uncharged pith ball will be attracted to a rod that has either a positive or a negative charge. B — Once the charged rod has contacted the ball, the ball will assume the same charge as the rod and it will be repelled by the rod.

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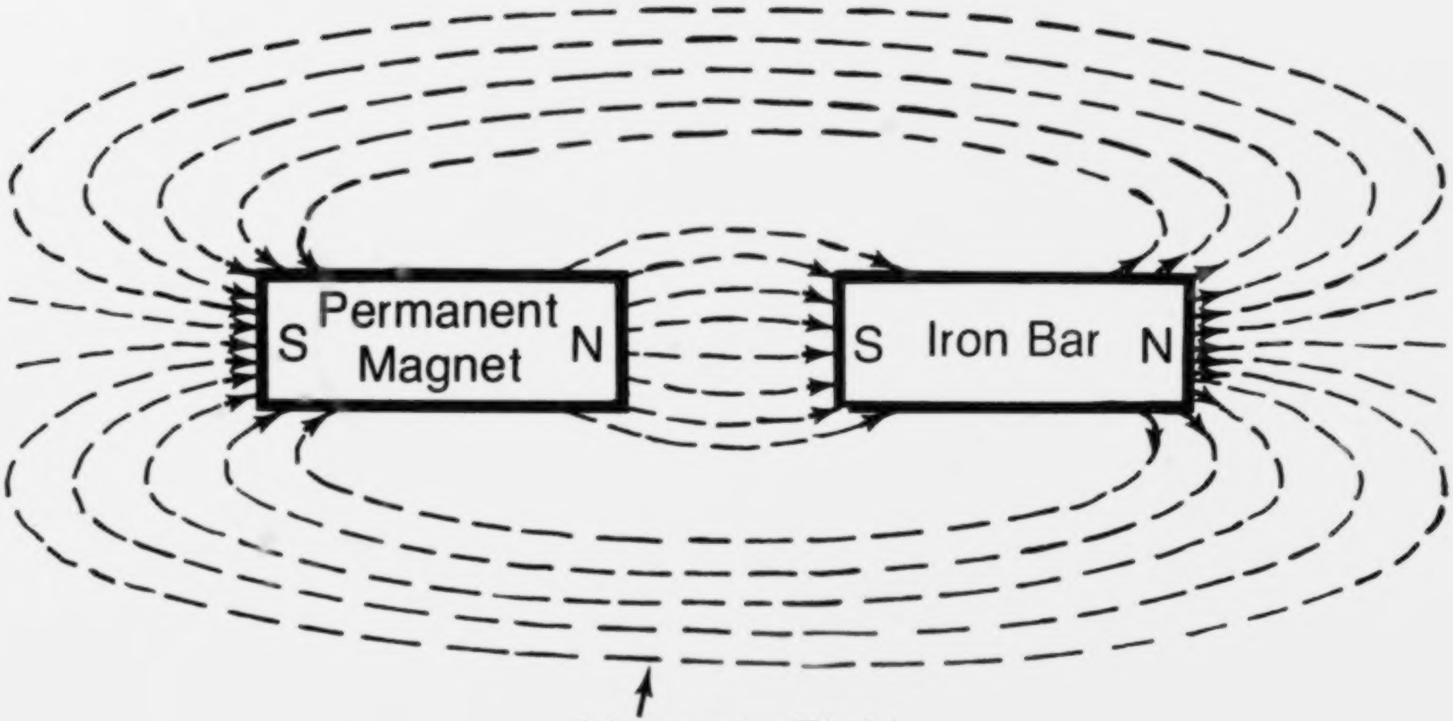
Induction

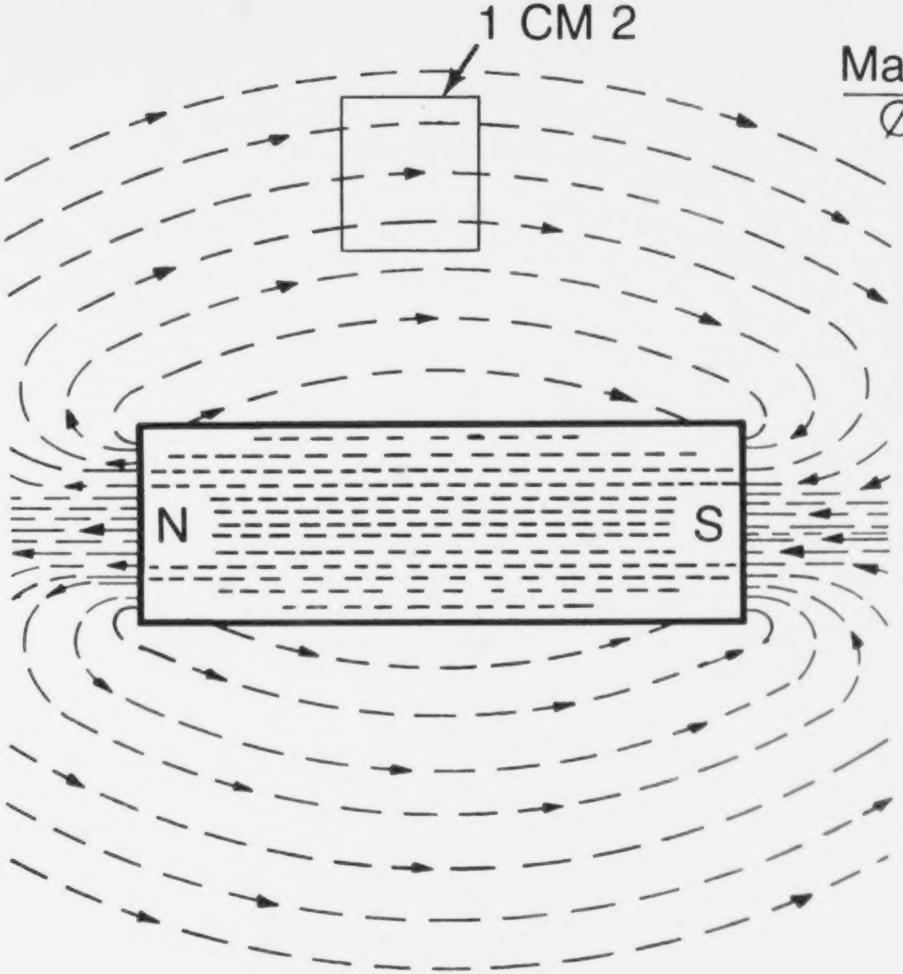

S
Permanent Magnet
N
S
Iron Bar
N
Magnetic Field

Note Opposite North-South Poles

Magnetic Flux and Flux Density

Flux Density
B = 4 G

Magnetic Flux
Ø = 14 Mx



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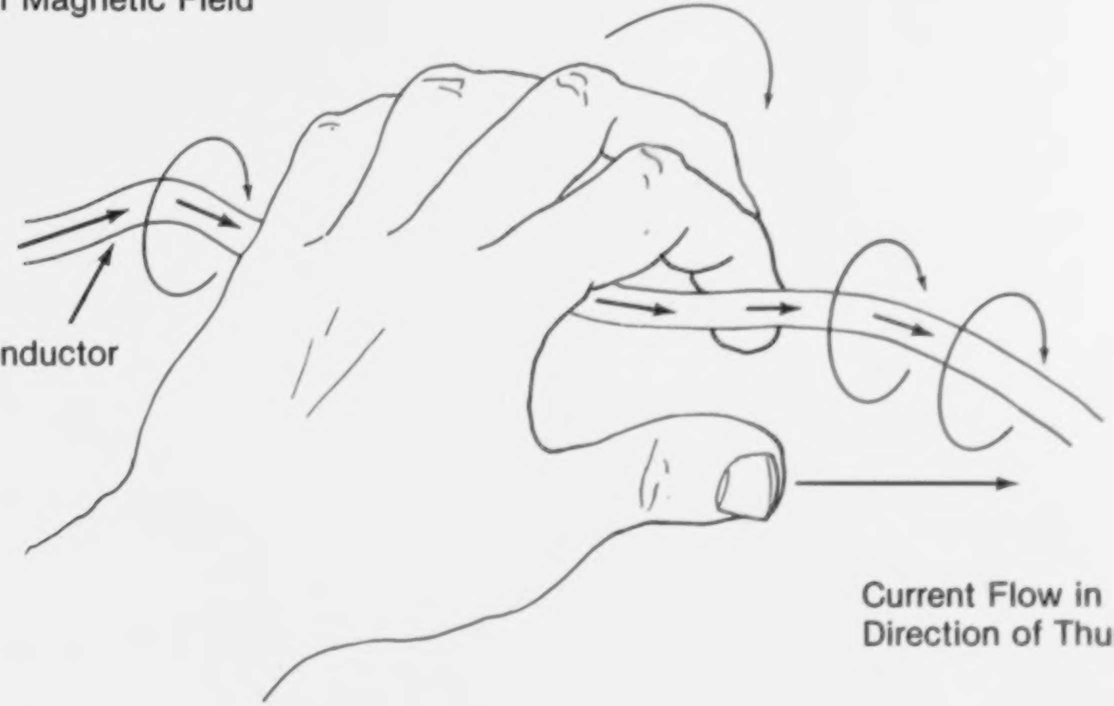
Left-Hand Rule for Magnetic Lines of Flux

Fingers Around Conductor Indicate Direction of Magnetic Field

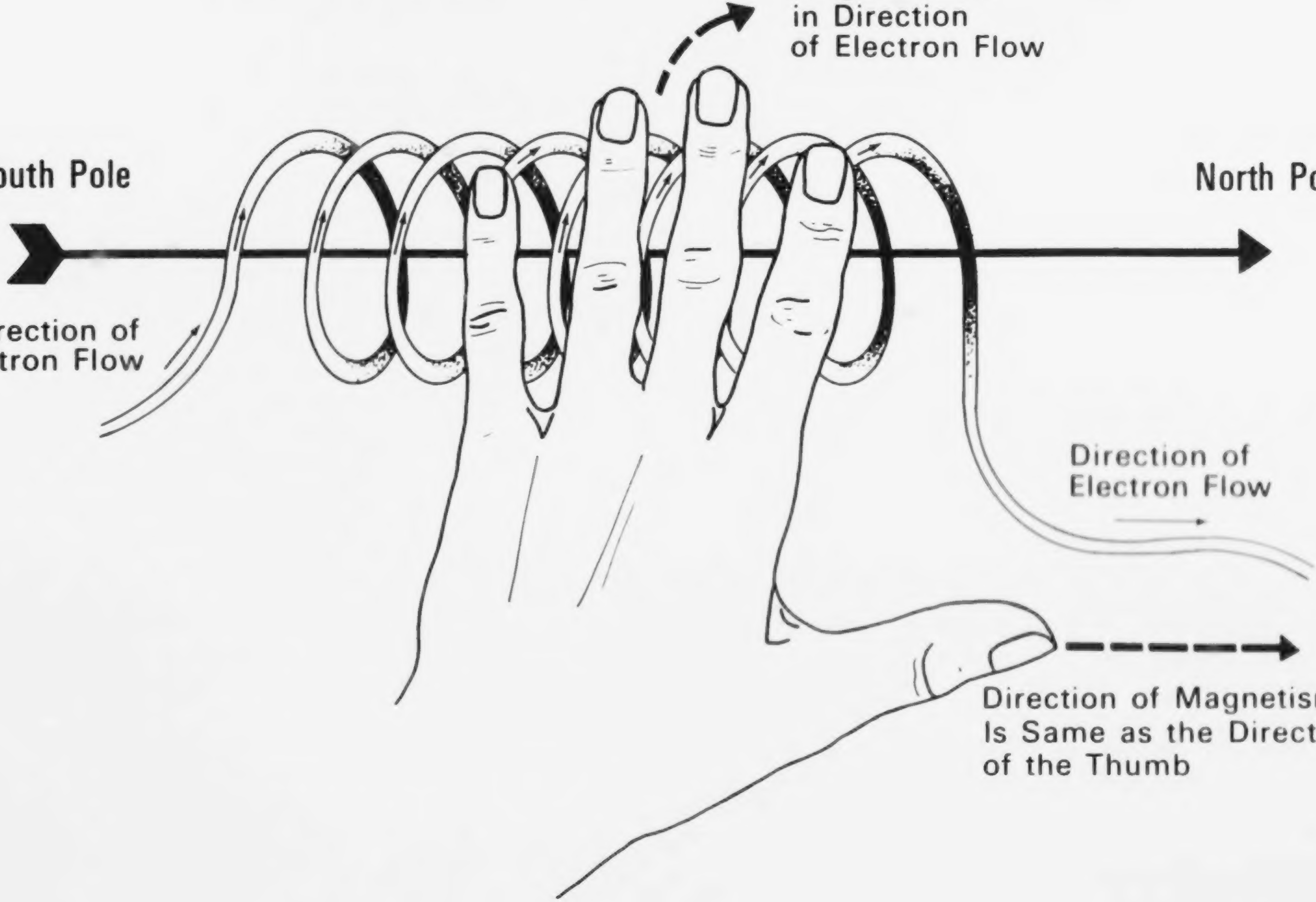


Conductor

Current Flow in Direction of Thumb

G105A-49

Left-Hand Rule for Electromagnets



Fingers Point
in Direction
of Electron Flow

South Pole

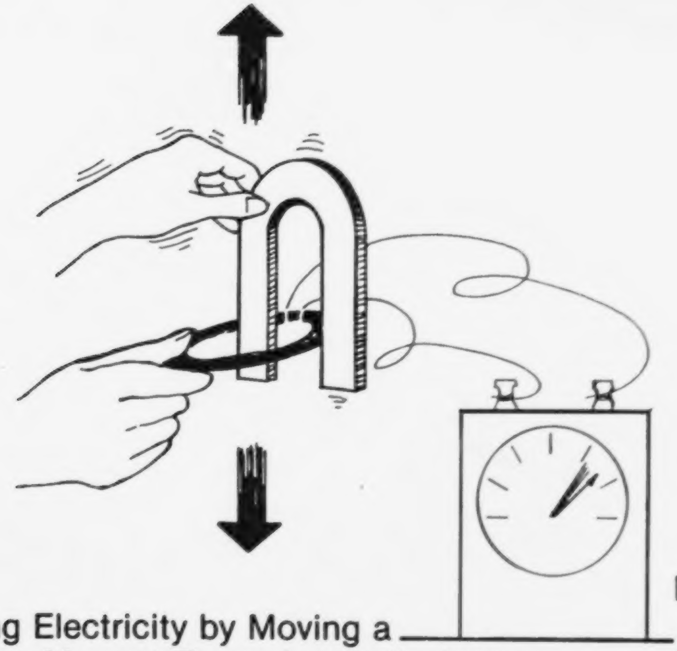
North Pole

Direction of
Electron Flow

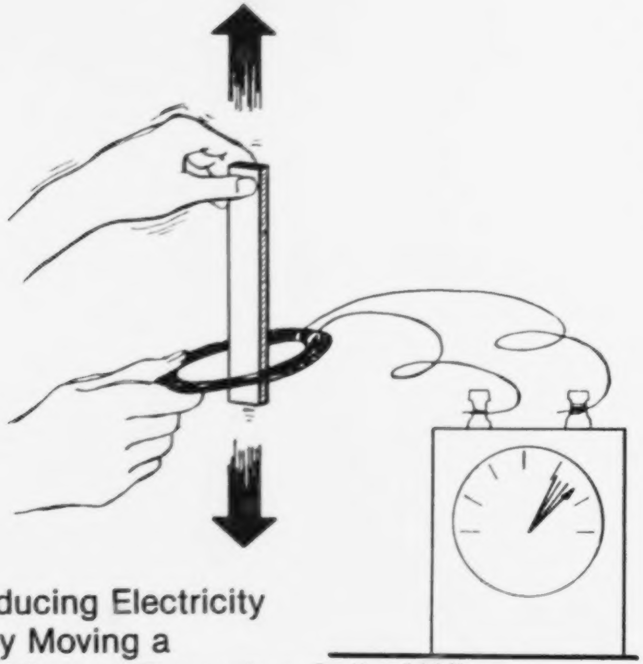
Direction of
Electron Flow

Direction of Magnetism
Is Same as the Direction
of the Thumb

Magnetism Produces Electricity

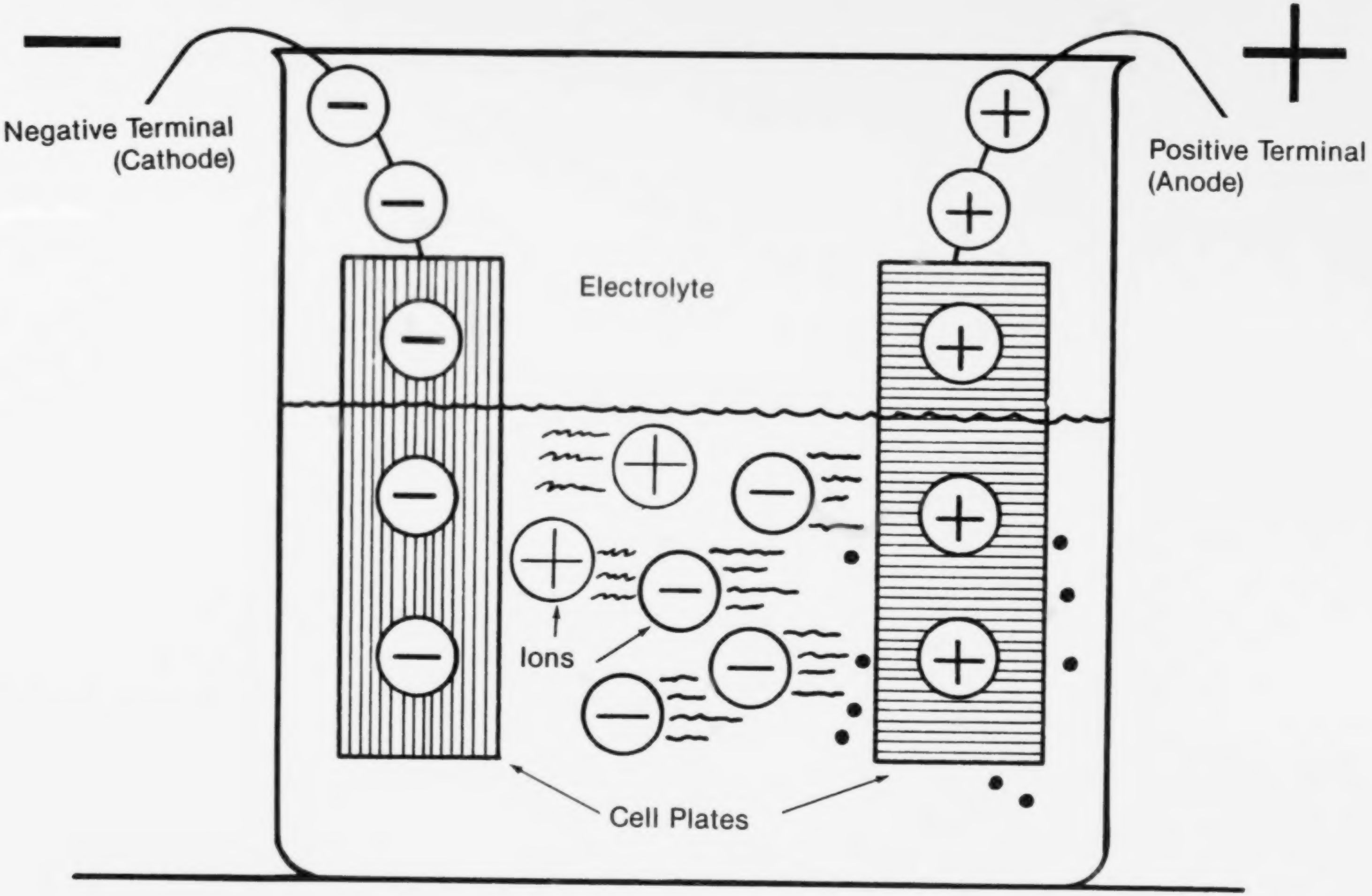


Producing Electricity by Moving a Horseshoe Magnet Through a Coil of Wire



Producing Electricity by Moving a Bar Magnet Through a Coil of Wire

Chemical Action Produces Electricity

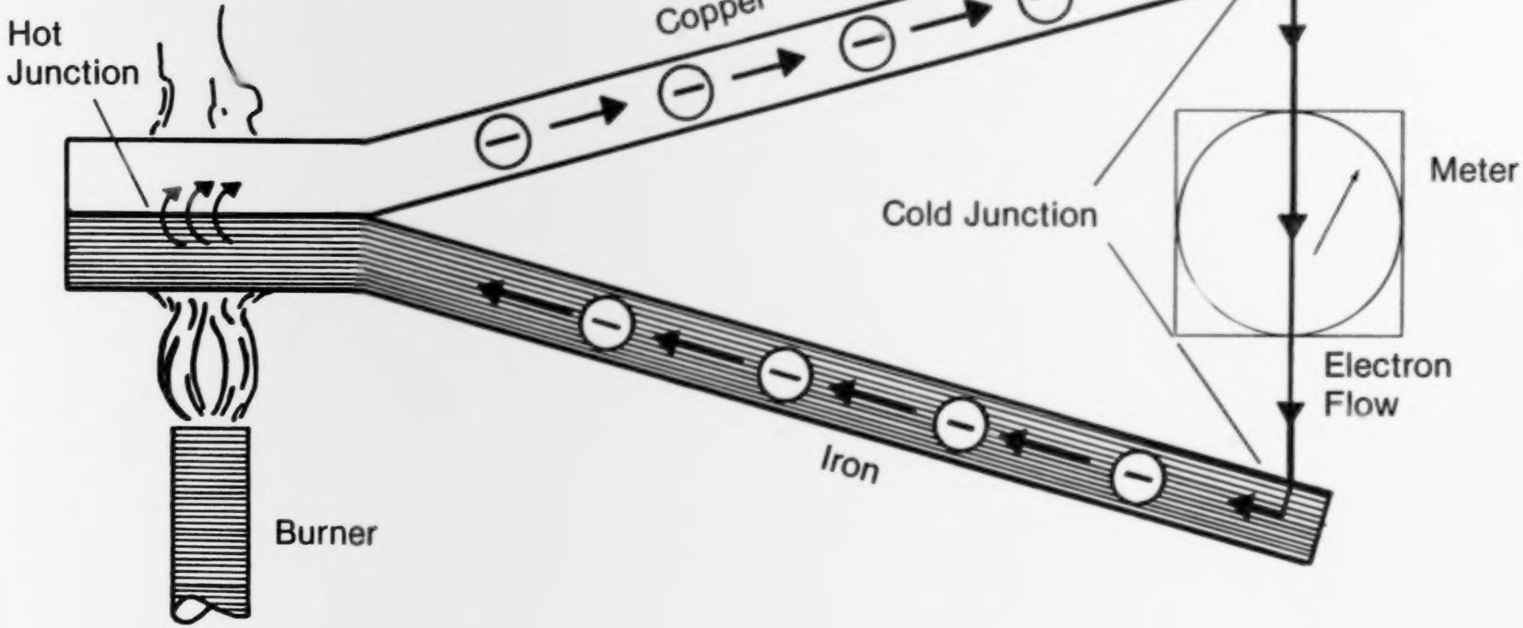

—
+
Negative Terminal (Cathode)
Positive Terminal (Anode)
Electrolyte
Ions
Cell Plates

G105A-55

TM #13

Heat Produces Electricity

(Thermocouple)



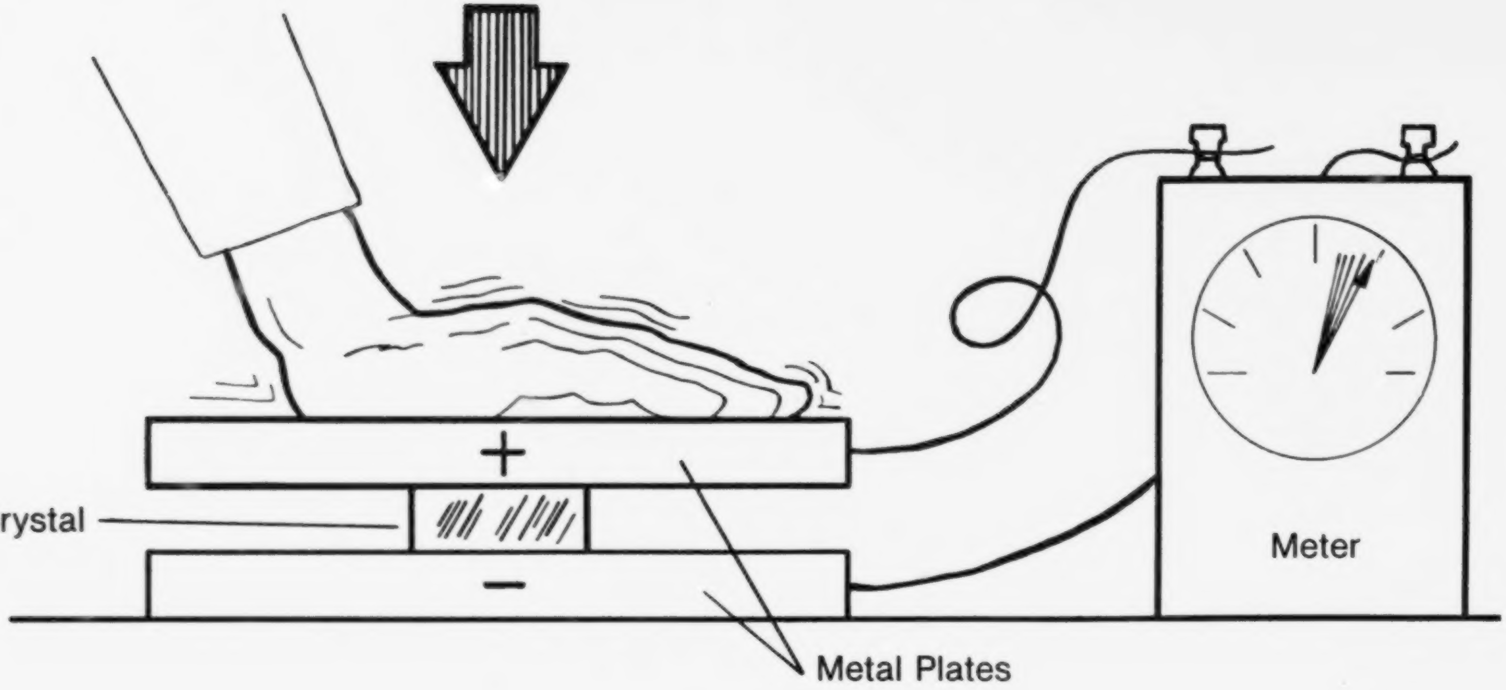
Hot Junction
Copper
Meter
Cold Junction
Electron Flow
Iron
Burner

G105A-57

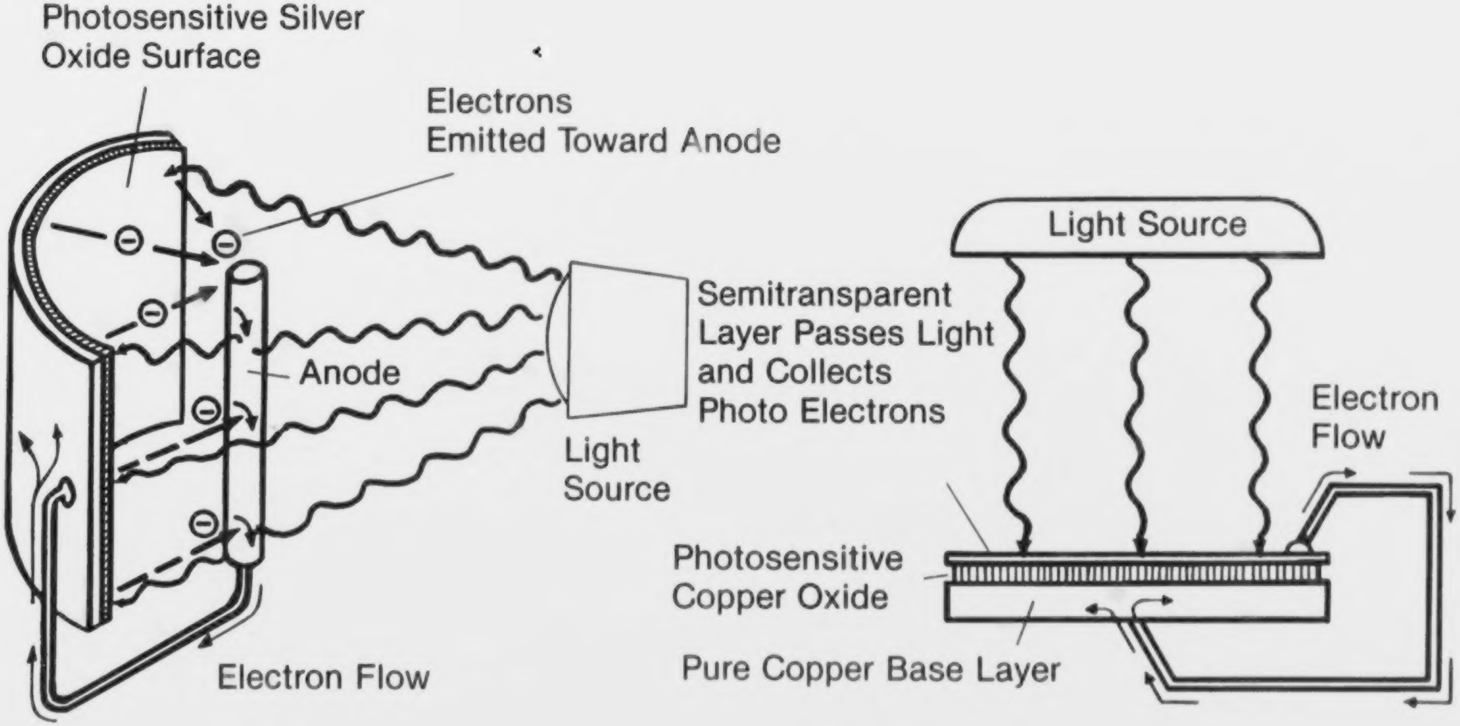
TM #14

Pressure Produces Electricity

(Piezoelectric Effect)


+
Crystal
−
Meter
Metal Plates

Light Produces Electricity


Photosensitive Silver Oxide Surface
Electrons Emitted Toward Anode
Anode
Light Source
Semitransparent Layer Passes Light and Collects Photo Electrons
Electron Flow
Light Source
Electron Flow
Photosensitive Copper Oxide
Pure Copper Base Layer

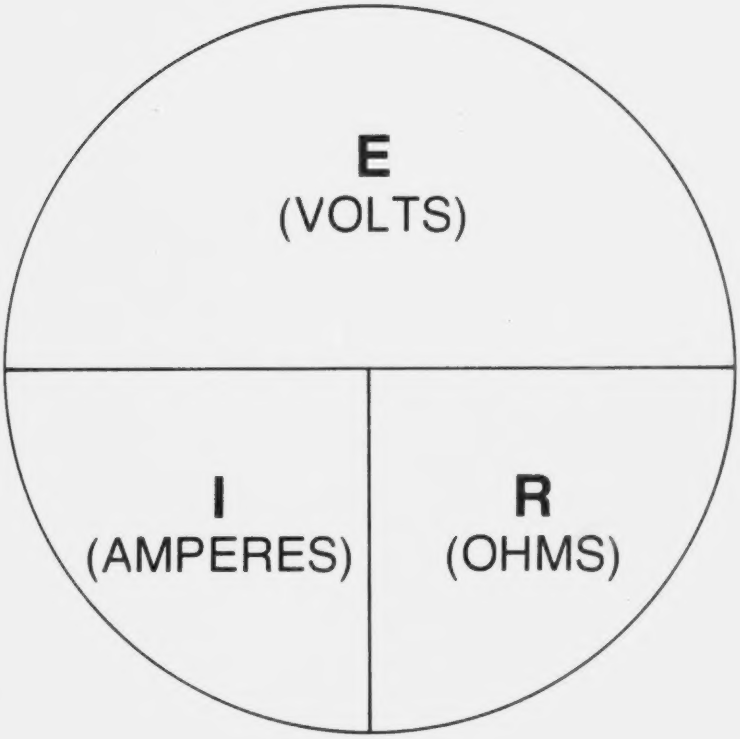
Ohm's Law

One volt is required to push one amp through one ohm resistance.

$$E = IR$$

Volts = Amperes x Ohms

Ohm's Law Magic Circle

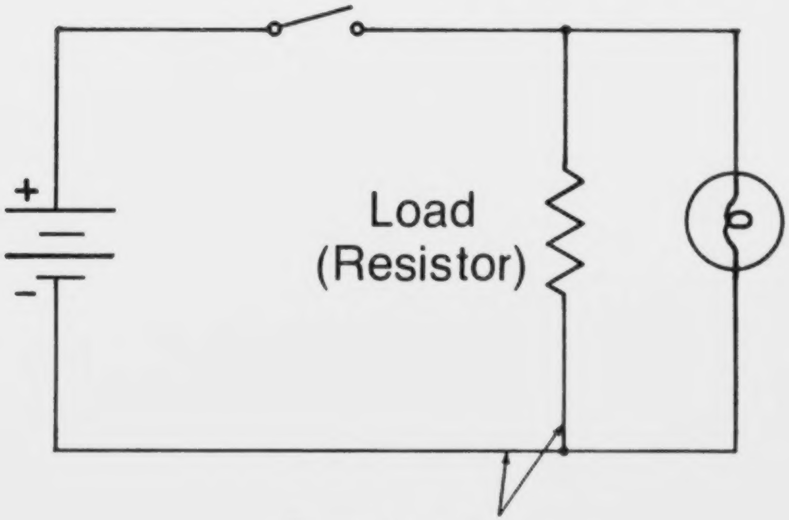

E
(VOLTS)
I
(AMPERES)
R
(OHMS)

$$E = IR$$

$$I = \frac{E}{R}$$

$$R = \frac{E}{I}$$

Schematic Showing Circuit Elements



Switch (Open)
(Manually Operated)

Power Source
(Battery)

Load
(Resistor)

Load
(Lamp)

Conductor
(Wires Connected)

Principle of Kirchhoff's Voltage Law

Sum of the voltage drops around any circuit is equal to the sum of the voltage applied

Principle of Kirchhoff's Current Law

Current entering a point or junction is equal to the current leaving that junction

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DETERMINE THE RELATIONSHIP OF VOLTAGE, CURRENT, RESISTANCE, AND POWER IN ELECTRICAL CIRCUITS
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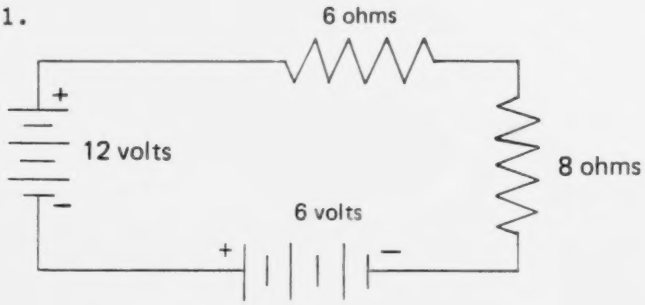
WORKBOOK SUPPLEMENT #1 - Apply Ohm's Law to Series Circuits With Multiple Components

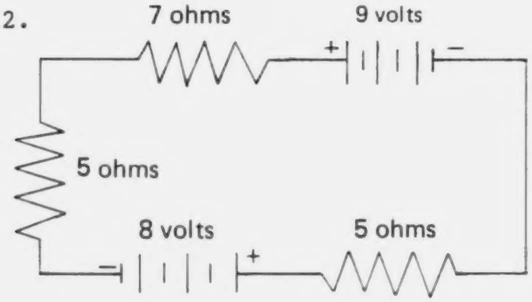
Ohm's law is used to solve for current, voltage, or resistance when the other two quantities are known. For a series circuit, the total resistance is simply the sum of all resistors. The total voltage is the sum of all the batteries if they are all the same direction. Apply Ohm's law to the following series circuits with multiple components. Find the indicated unknown in each of the following circuits. Write the correct answers in the blanks.

1.



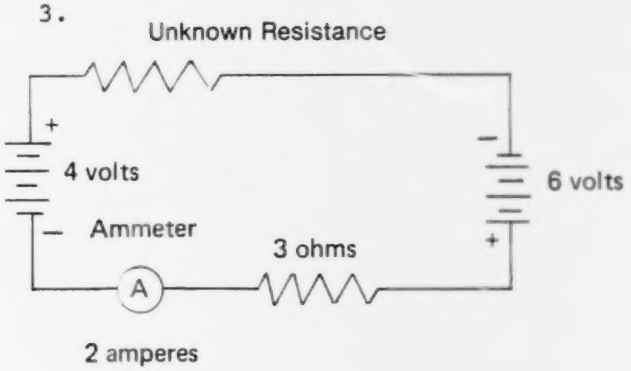
I = ________

2.



I = ________

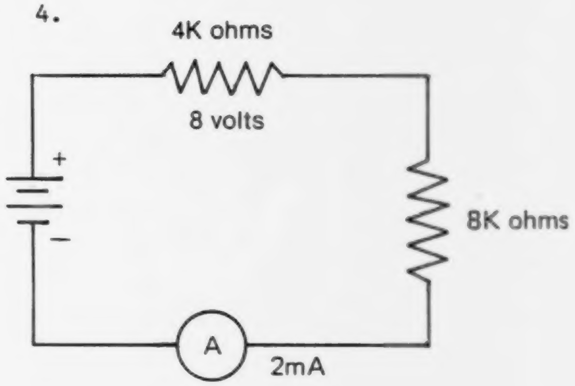
3.


Unknown Resistance
+
4 volts
–
Ammeter
3 ohms
A
2 amperes
–
6 volts
+

If 2 amperes of current are flowing, what must be the value of the unknown resistor?

R_x = ____________

4.

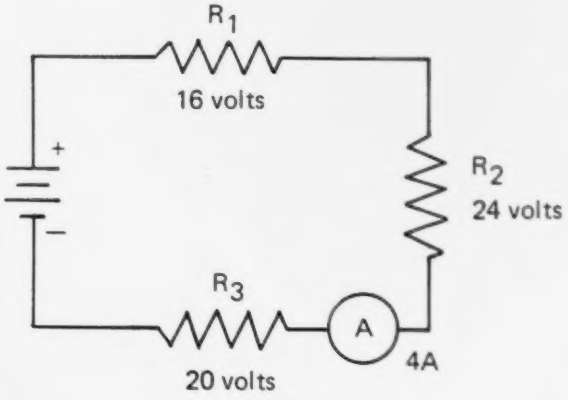

4K ohms
8 volts
+
–
8K ohms
A
2mA

R_t = ____________

E_a = ____________

(NOTE: 2 mA = 0.002A.)

5.


R1
16 volts
+
–
R2
24 volts
R3
20 volts
A
4A

a. E_a = __________

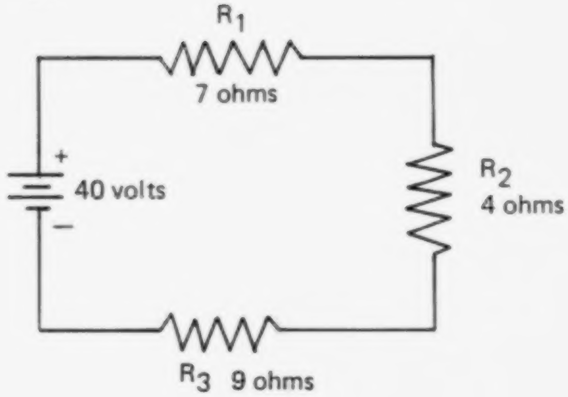
b. R_1 = __________

c. R_2 = __________

d. R_3 = __________

e. R_t = __________

6.


R_1
7 ohms
+
40 volts
−
R_2
4 ohms
R_3 9 ohms

a. R_t = ________
b. I_t = ________
c. E_{R1} = ________
d. E_{R2} = ________
e. E_{R3} = ________

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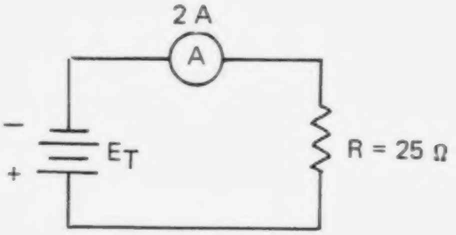
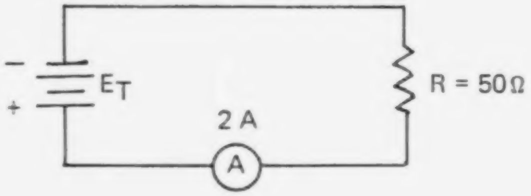
WORKBOOK SUPPLEMENT #2 - Determine Total Voltage in a Series Circuit

Ohm's law has many applications in electrical circuits. The following problems will allow you to develop competency in analyzing circuits and solving for values using Ohm's law. Determine total voltage in the following series circuits. Write the correct answers in the blanks.

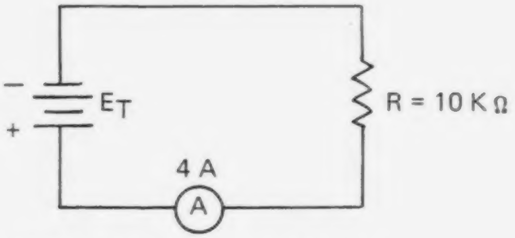
1. E_T = ________



2. E_T = ________

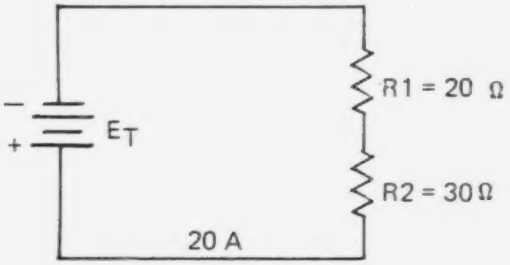


3. E_T = ________

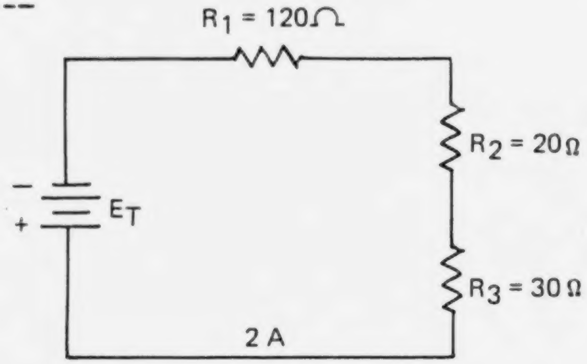


(NOTE: 10 KΩ = 10,000Ω.)

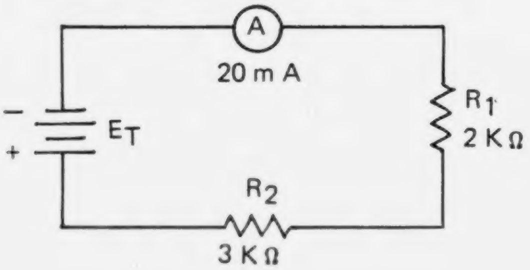
4. E_T = ________



5. E_T = ________


R1 = 120Ω
R2 = 20Ω
ET
R3 = 30Ω
2 A
−
+

6. E_T = ________


A
20 m A
ET
R1
2 KΩ
R2
3 KΩ
−
+

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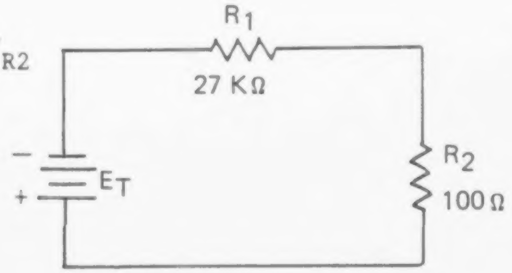
WORKBOOK SUPPLEMENT #3 - Determine Voltage Drops Across Resistance

The following problems increase your competency in determining voltage drops across resistance in series circuits. Write the correct answers in the blanks.

1. True or False?

_________ V_{R1} is greater than V_{R2}

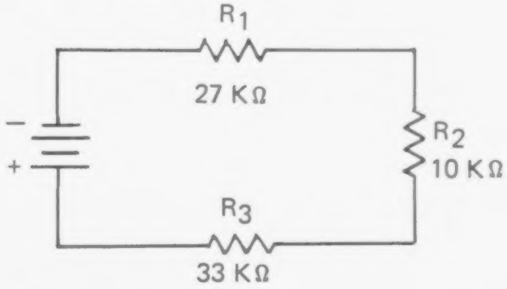

R1
27 KΩ
−
+
ET
R2
100 Ω

2. The largest voltage drop is

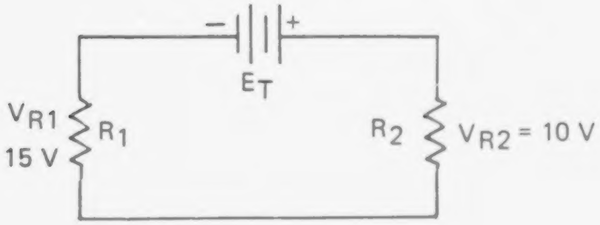
____a. V_{R1}

____b. V_{R2}

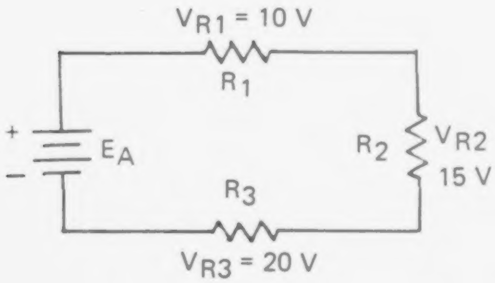
____c. V_{R3}


R1
27 KΩ
−
+
R2
10 KΩ
R3
33 KΩ

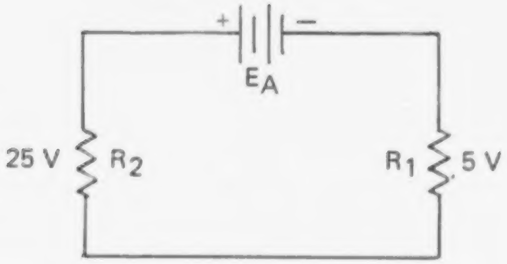
3. E_T = _________


−
+
ET
VR1
15 V
R1
R2
VR2 = 10 V

4. E_A = _________


VR1 = 10 V
R1
+
−
EA
R2
VR2
15 V
R3
VR3 = 20 V

5. E_A = _________



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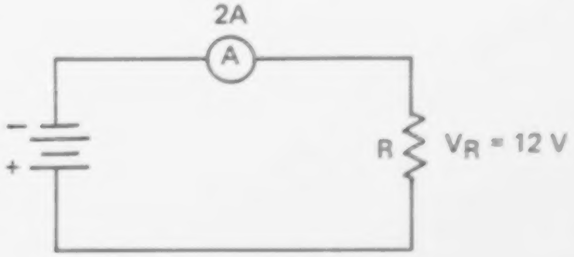
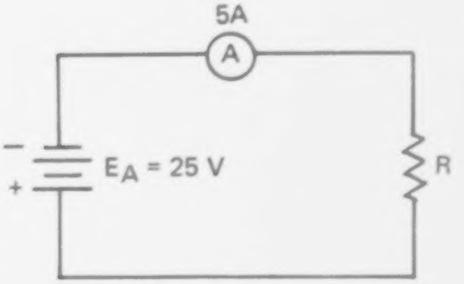
WORKBOOK SUPPLEMENT #4 - Determine Total Resistance in a Series Circuit

As an aviation maintenance technician you will be responsible for troubleshooting electrical circuits. The following problems will allow you to develop competency in analyzing series circuits to determine total resistance in series circuits. Write the correct answers in the blanks.

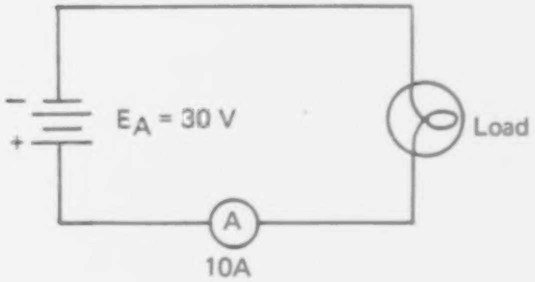
1. R_T = ________



2. R_T = ________



3. R_T = ________



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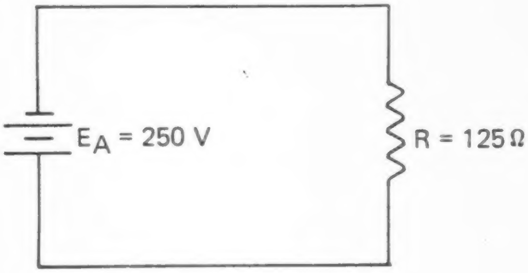
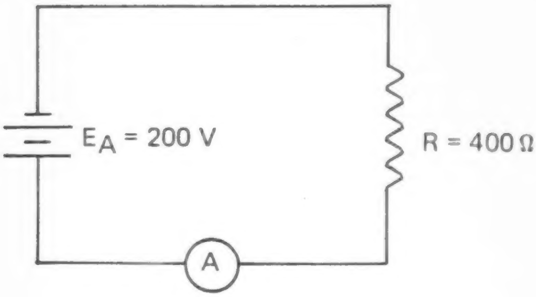
WORKBOOK SUPPLEMENT #5 - Determine Current in a Series Circuit

The following problems will allow you to develop competency in using voltage and resistance values to determine current flow in series circuits. Determine the current in the following series circuits. Be sure to indicate units. Write the correct answers in the blanks.

1. I = ________

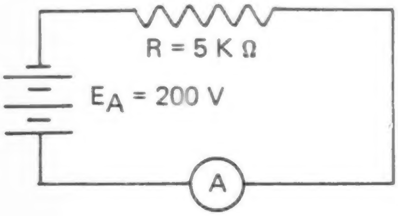


2. I = ________



3. I = ________

(NOTE: Give answers in milliamperes.)



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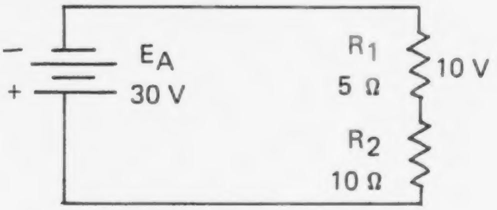
WORKBOOK SUPPLEMENT #6 - Determine Unknown Circuit Values in a Series Circuit

The following problems will give you practice in determining unknown circuit values within a series circuit using Ohm's law. Write the correct answers in the blanks.

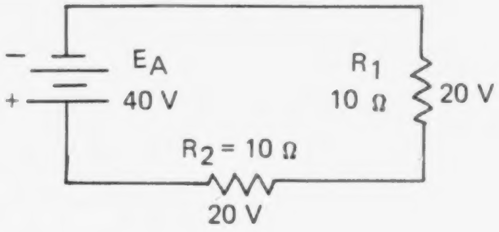
(NOTE: The Ohm's law formula applies to all parts of a circuit, and all resistors are equal in value.)

1. I_{R1} = _________



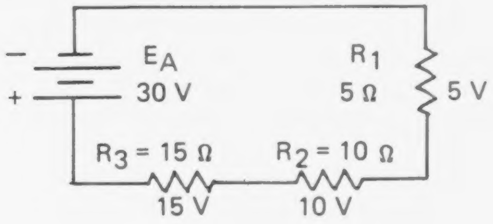
−
+
E_A
30 V
R1
5 Ω
10 V
R2
10 Ω

2. I_{R2} = _________



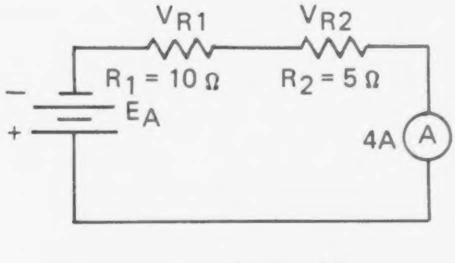
−
+
E_A
40 V
R1
10 Ω
20 V
R2 = 10 Ω
20 V

3. I_{R3} = _________



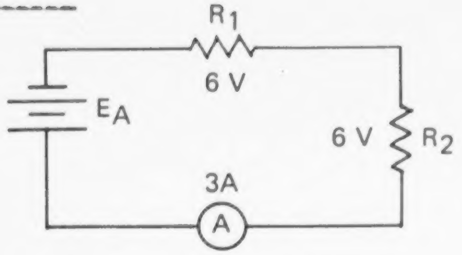
−
+
E_A
30 V
R1
5 Ω
5 V
R3 = 15 Ω
15 V
R2 = 10 Ω
10 V

4. V_{R2} = _________

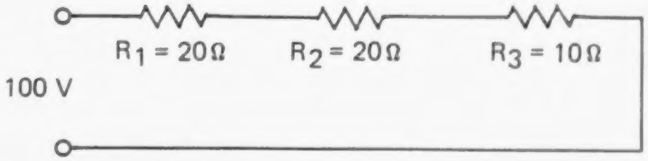


VR1
VR2
R1 = 10 Ω
R2 = 5 Ω
−
+
E_A
4A
A

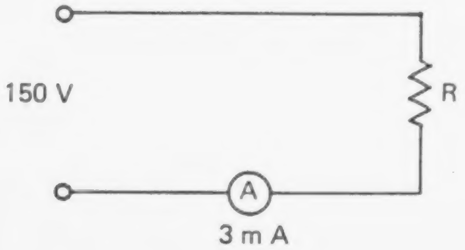
5. R_2 = ________


R_1
6 V
E_A
6 V
R_2
3A
A

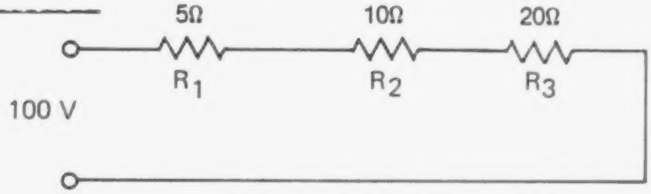
6. V_3 = ________


$R_1 = 20\Omega$
$R_2 = 20\Omega$
$R_3 = 10\Omega$
100 V

7. R = ________



8. V_1 = ________


5Ω
10Ω
20Ω
R_1
R_2
R_3
100 V

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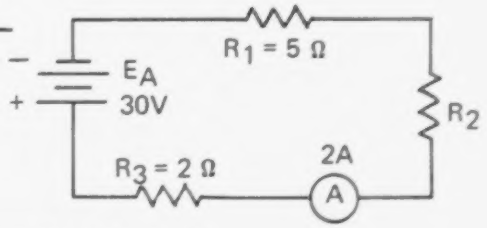
WORKBOOK SUPPLEMENT #7 - Determine Unknown Values in a Resistive Series Circuit

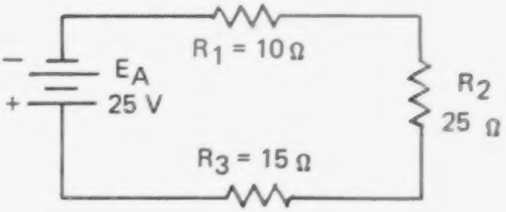
The following problems will allow you to further develop competency in using Ohm's law to determine unknown values in resistive series circuits. Write the correct answers in the blanks.

1. R_2 = ________



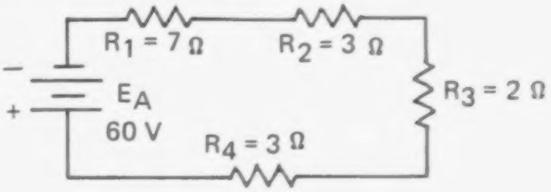
(NOTE: First solve for R_T.)

2. V_{R1} = ________



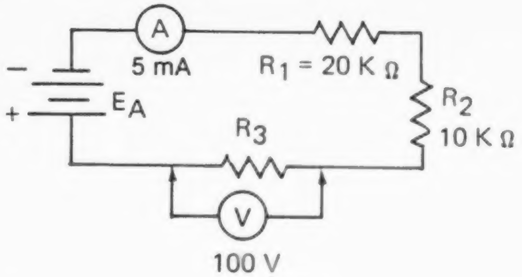
(NOTE: To solve for any one part of a circuit, you must have two known values of that part. If solving for volts, you must first find amps and ohms.)

3. Determine the quantities indicated.



a. R_T = ____
b. I_T = ____
c. V_{R1} = ____
d. I_{R3} = ____
e. V_{R2} = ____
f. V_{R3} = ____
g. V_{R4} = ____
h. I_{R4} = ____

4. Determine the quantities indicated.


A
5 mA
R1 = 20 K Ω
−
+
EA
R2
10 K Ω
R3
V
100 V

a. I_T = ____

b. V_{R2} = ____

c. R_3 = ____

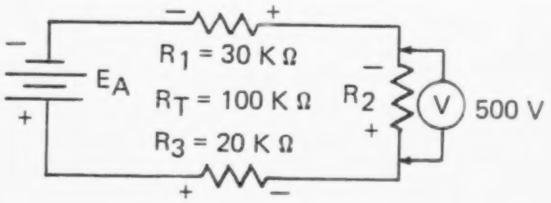
d. V_{R1} = ____

e. I_{R1} = ____

f. E_A = ____

(NOTE: 5mA = 0.005 A.)

5. Determine the quantities indicated.


− +
−
EA
+
R1 = 30 K Ω
RT = 100 K Ω
R3 = 20 K Ω
R2
−
+
V
500 V
+ −

a. R_2 = ____

b. I_{R3} = ____

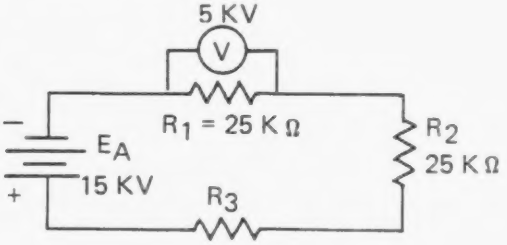
c. I_t = ____

d. V_{R1} = ____

e. V_{R3} = ____

f. E_A = ____

6. Determine the quantities indicated.


5 KV
V
R1 = 25 K Ω
−
EA
15 KV
+
R2
25 K Ω
R3

a. I_t = ____

b. V_{R2} = ____

c. R_3 = ____

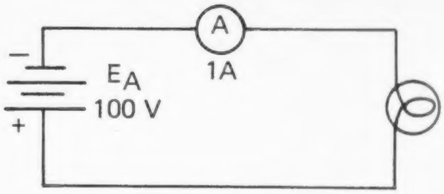
d. V_{R3} = ____

e. R_T = ____

f. I_{R3} = ____

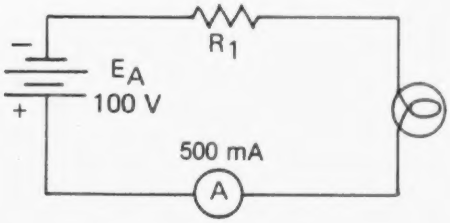
7. What resistance value will the lamp have?

R_L = ________



8. In this circuit, if you wanted the lamp in problem 7 to operate at 50 V, what would the value of R_1 have to be?

R_1 = ________



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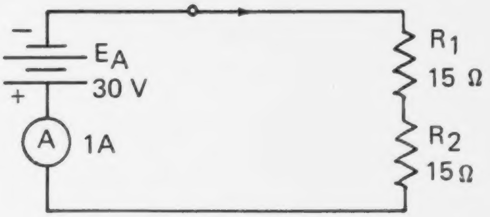
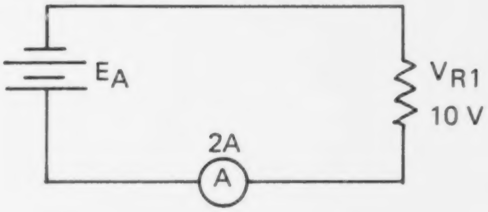
WORKBOOK SUPPLEMENT #8 - Compute the Power Dissipated in a Resistive Series Circuit

The following problems will allow you to develop competency in computing the power dissipated in resistive series circuits. Write the correct answers in the blanks.

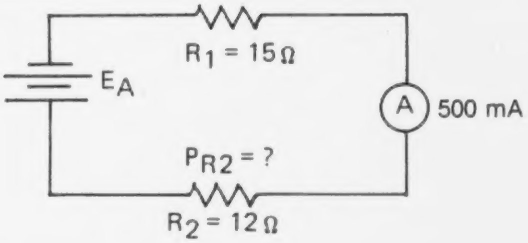
1. P_T = ________


−
E_A
30 V
+
A
1A
R1
15 Ω
R2
15 Ω

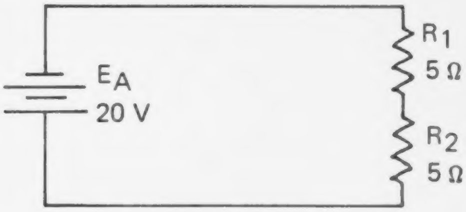
2. P_{R1} = ________


E_A
V_R1
10 V
2A
A

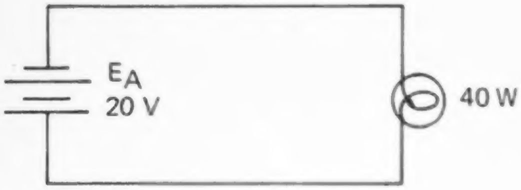
3. P_{R2} = ________


R1 = 15 Ω
E_A
A
500 mA
P_R2 = ?
R2 = 12 Ω

4. P_T = ________


E_A
20 V
R1
5 Ω
R2
5 Ω

5. If the lamp is using 40 watts, the current equals ____________________



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WORKBOOK SUPPLEMENT #9 - Calculate Current and Voltage in Parallel Circuits

The following problems will allow you to develop competency in calculating values for current and voltage in parallel circuits. Write the correct answers in the blanks.

1. Calculate quantities indicated.

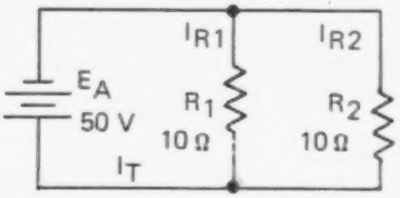
a. E_{R1} = ________

b. I_{R1} = ________

c. E_{R2} = ________

d. I_{R2} = ________

e. I_T = ________



I_{R1}
I_{R2}
E_A
50 V
R_1
10 Ω
R_2
10 Ω
I_T

2. Calculate quantities indicated.

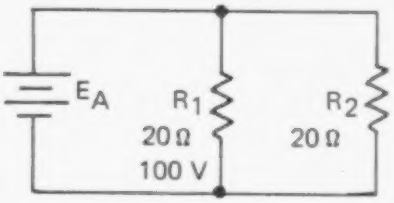
a. I_{R1} = ________

b. E_{R2} = ________

c. I_{R2} = ________

d. I_T = ________

e. E_A = ________



E_A
R_1
20 Ω
100 V
R_2
20 Ω

3. Calculate quantities indicated.

a. I_{R1} = ________

b. I_{R2} = ________

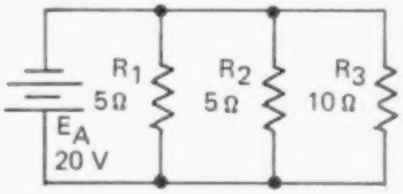
c. I_{R3} = ________

d. I_T = ________

e. E_{R1} = ________

f. E_{R2} = ________

g. E_{R3} = ________



R_1
5 Ω
R_2
5 Ω
R_3
10 Ω
E_A
20 V

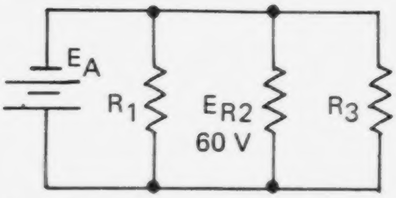
WORKBOOK SUPPLEMENT #9

4. Calculate quantities indicated.

a. E_{R1} = __________

b. E_{R3} = __________

c. E_A = __________


E_A
R_1
E_{R2}
60 V
R_3

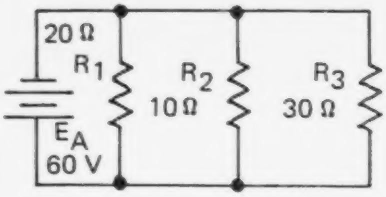
5. Calculate quantities indicated.

a. I_1 = __________

b. I_2 = __________

c. E_3 = __________

d. I_T = __________


20 Ω
R_1
R_2
10 Ω
R_3
30 Ω
E_A
60 V

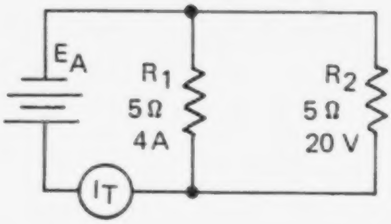
6. Calculate quantities indicated.

a. I_2 = __________

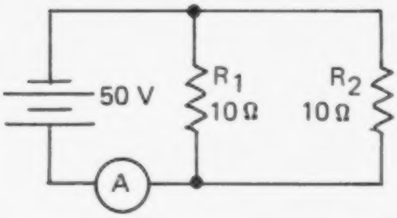
b. I_T = __________

c. E_{R1} = __________

d. E_A = __________


E_A
R_1
5 Ω
4 A
R_2
5 Ω
20 V
I_T

7. If you measured current where ammeter is located, what should it indicate? ____________________


50 V
R_1
10 Ω
R_2
10 Ω
A

8. Calculate quantities indicated.

a. I_1 = __________

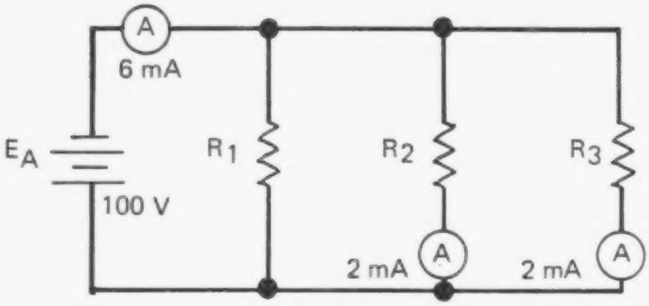
b. E_{R1} = __________

c. E_A = __________

d. I_T = __________

e. E_{R2} = __________

f. E_{R3} = __________


A
6 mA
E_A
100 V
R_1
R_2
R_3
2 mA
A
2 mA
A

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WORKBOOK SUPPLEMENT #10 - Calculate Resistance in Parallel Circuits

The following problems will allow you to develop competency in calculating resistance in parallel circuits. Write the correct answers in the blanks.

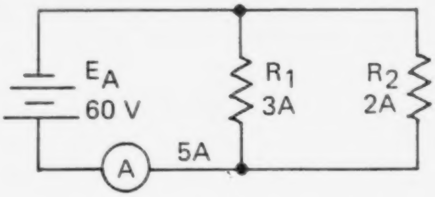
1. Calculate quantities indicated.

a. R_1 = ________

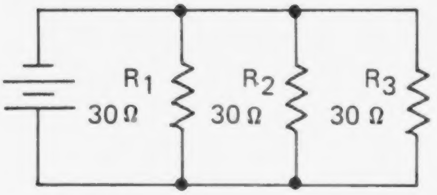
b. R_2 = ________

c. R_T = ________

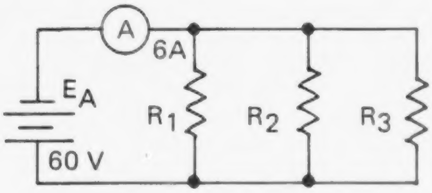
d. $\frac{E_A}{I_T}$ = ________



2. R_T = ________

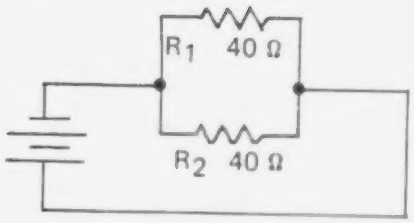


3. a. R_T = ________

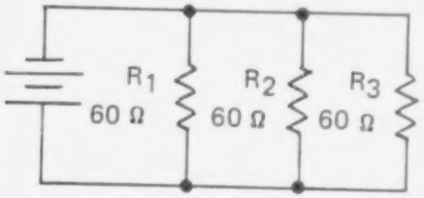


b. If the three resistors are equal in value,
R_1 = ______ ohms.

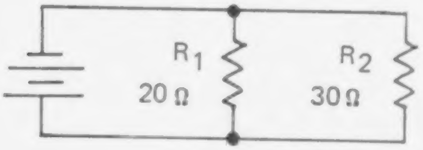
4. R_T = ________


R1 40 Ω
R2 40 Ω

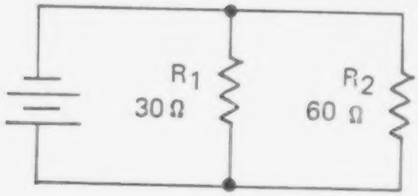
5. R_T = ________


R1 60 Ω
R2 60 Ω
R3 60 Ω

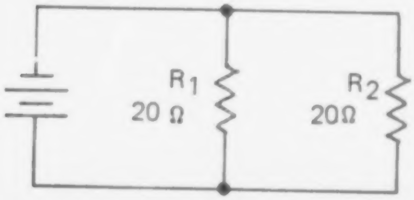
6. R_T = ________


R1 20 Ω
R2 30 Ω

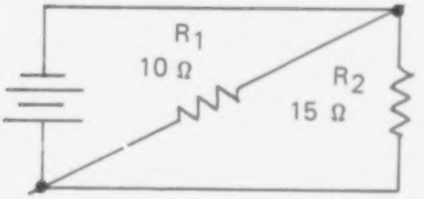
7. R_T = ________


R1 30 Ω
R2 60 Ω

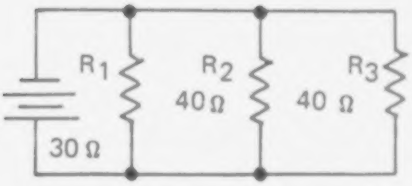
8. R_T = ________


R1 20 Ω
R2 20Ω

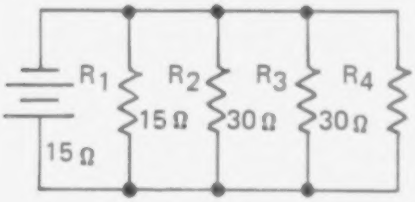
9. R_T = ________


R1
10 Ω
R2
15 Ω

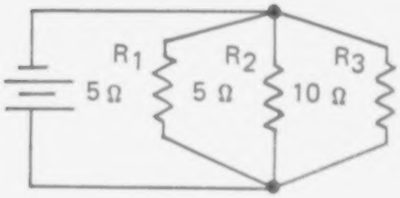
10. R_T = ________


R1
R2
40 Ω
R3
40 Ω
30 Ω

11. R_T = ________

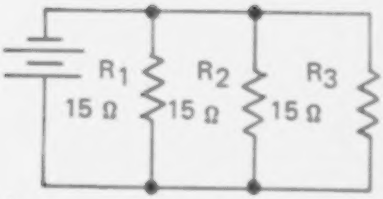

R1
R2
R3
R4
15 Ω
30 Ω
30 Ω
15 Ω

12. R_T = ________

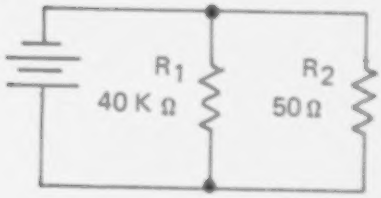

R1
5 Ω
R2
5 Ω
R3
10 Ω

13. Match

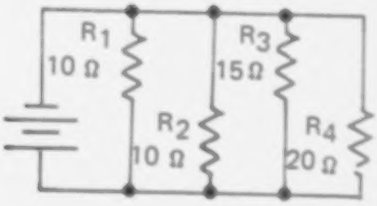
____a.


R1
15 Ω
R2
15 Ω
R3
15 Ω

____b.


R1
40 K Ω
R2
50 Ω

____c.


R1
10 Ω
R2
10 Ω
R3
15 Ω
R4
20 Ω

1. Unequal branch method (product over sum)
2. Reciprocal method
3. Equal branch method

(NOTE: Method 2 can, naturally, be used for all. Choose the fastest method.)

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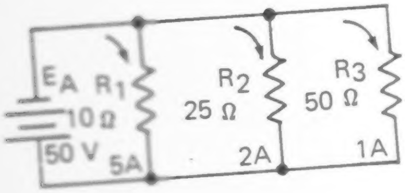
WORKBOOK SUPPLEMENT #11 - Calculate Power in Parallel Circuits

The following problems will allow you to develop competency in calculating power in parallel circuits. Write the correct answers in the blanks.

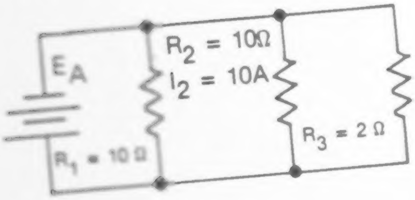
1. Calculate P_T



E
A
R1
10 Ω
50 V
5A
R2
25 Ω
2A
R3
50 Ω
1A

______ Watts

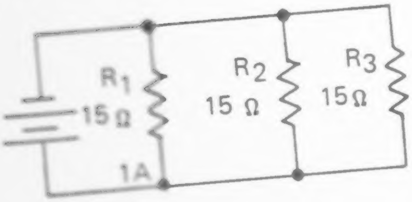
2. Calculate P_T



E
A
R1 = 10 Ω
R2 = 10Ω
I2 = 10A
R3 = 2 Ω

______ Watts

3. Calculate P_T



R1
15 Ω
1A
R2
15 Ω
R3
15Ω

______ Watts

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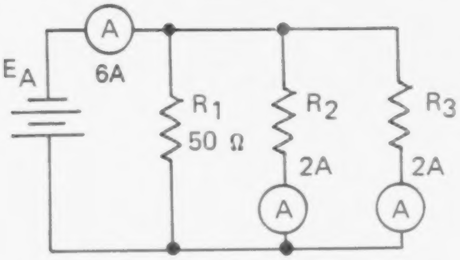
WORKBOOK SUPPLEMENT #12 - Calculate Various Values in Parallel Circuits

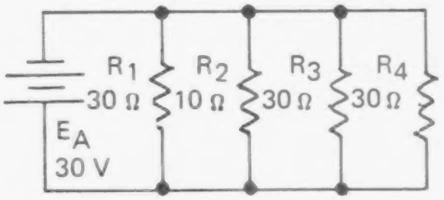
The following problems will allow you to further develop your competency in calculating voltage, resistance, current, and power in parallel circuits. Write the correct answers in the blanks.

1. Calculate quantities indicated.


A
E_A
6A
R_1
50 Ω
R_2
2A
A
R_3
2A
A

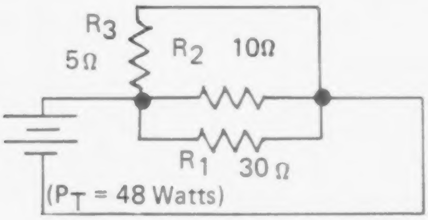
a. E_{R1} = ________
b. E_a = ________
c. R_T = ________
d. R_2 = ________
e. R_3 = ________
f. P_T = ________

2. Calculate quantities indicated.


R_1
30 Ω
R_2
10 Ω
R_3
30 Ω
R_4
30 Ω
E_A
30 V

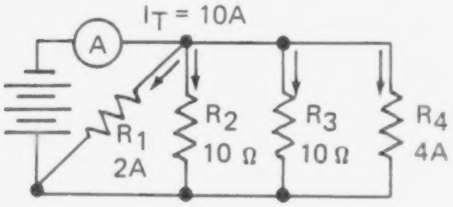
a. R_T = ________
b. I_1 = ________
c. I_2 = ________
d. I_3 = ________
e. I_4 = ________
f. I_T = ________

3. Calculate quantities indicated.


R_3
5Ω
R_2 10Ω
R_1 30 Ω
(P_T = 48 Watts)

a. R_T = ________
b. I_T = ________
c. E_a = ________
d. I_{R1} = ________

4. Calculate quantities indicated.


$I_T = 10A$
A
R_1
2A
R_2
10 Ω
R_3
10 Ω
R_4
4A

a. E_a = ________

b. R_4 = ________

c. I_{R2} = ________

d. I_{R3} = ________

e. R_T = ________

f. P_T = ________

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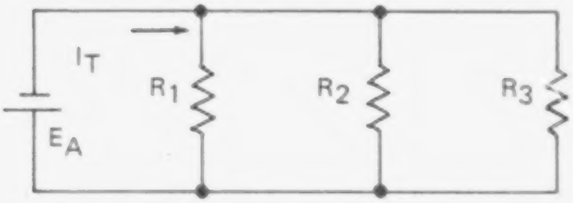
WORKBOOK SUPPLEMENT #13 - Perform Circuit Analysis for Parallel Circuits

The following problems will allow you to demonstrate your knowledge of circuit analysis for parallel circuits. Insert arrow symbols in the blocks to indicate increase (↑), decrease (↓) or remain the same (→).

(Use this circuit for problems 1 and 2)



1.

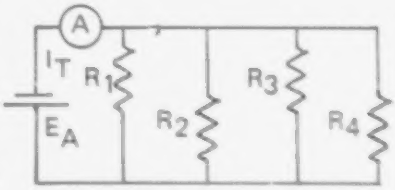
E_A ↓											
	I_T	R_T	P_T	I_{R1}	I_{R2}	I_{R3}	E_{R1}	E_{R2}	E_{R3}	R_1	R_2	R_3

2.

E_A ↑											
	I_T	R_t	P_t	I_{R1}	I_{R2}	I_{R3}	E_{R1}	E_{R2}	E_{R3}	R_1	R_2	R_3

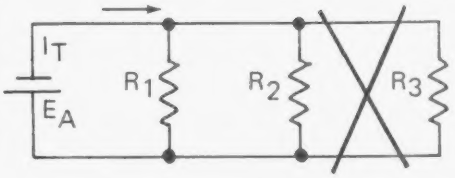
3.

Add R_4												
	I_t	R_t	E_t	P_t	R_1	R_3	E_{R1}	E_{R2}	E_{R3}	I_{R1}	I_{R2}	I_{R3}



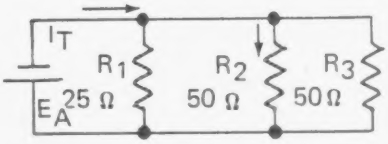
4.

Remove R_3										
	I_T	R_T	E_T	P_T	E_{R1}	E_{R2}	R1	R2	I_{R1}	I_{R1}


I_T
E_A
R_1
R_2
R_3

5.

R_2 ↓												
	I_T	R_T	E_T	P_T	R1	R3	E_{R1}	E_{R2}	E_{R3}	I_{R1}	I_{R2}	I_{R3}

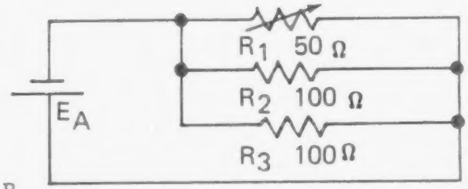

I_T
E_A
R_1
25 Ω
R_2
50 Ω
R_3
50 Ω

6. There are three parts to this problem.

a. Increase E_A

b. Remove R_3

c. Change R_1 to 100 ohms; that is, increase R_1


E_A
R_1 50 Ω
R_2 100 Ω
R_3 100 Ω

For each of the three problems, assume that the other elements remain constant.

E_A ↑			▨										
Remove R_3							▨			▨			▨
R_1 ↑											▨		
	I_t	R_t	E_t	P_t	I_{R1}	I_{R2}	I_{R3}	E_{R1}	E_{R2}	E_{R3}	R1	R2	R3

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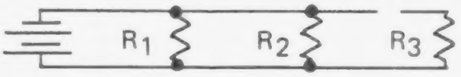
WORKBOOK SUPPLEMENT #14 - Analyze Shorts and Opens in Parallel Circuits

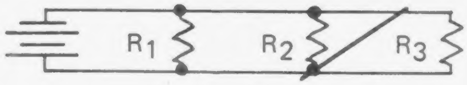
The following problems will allow you to demonstrate your knowledge in analyzing shorts and opens in parallel circuits. Write the correct answer in the blanks.

1. Match

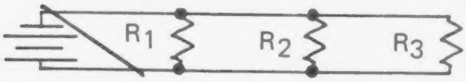
_____ a.



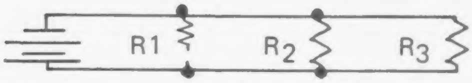
_____ b.



_____ c.

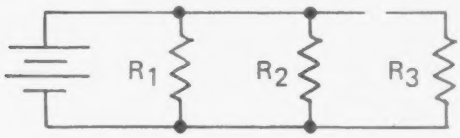


_____ d.



1. Short
2. Main line open
3. Branch open

2. Locate the open or short shown in the schematic, then answer the questions below comparing circuit (Figure 1) to the primary connected circuit (Figure 2) using R_1, R_2, and R_3 in parallel.



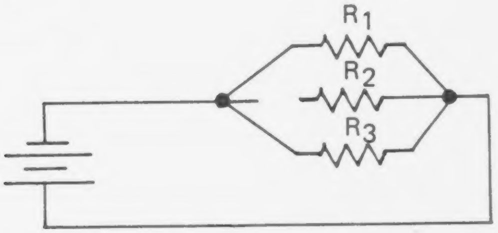
a. I_T would ____________________ (increase/decrease)

b. R_T would ____________________ (increase/decrease)

c. P_T would ____________________ (increase/decrease)

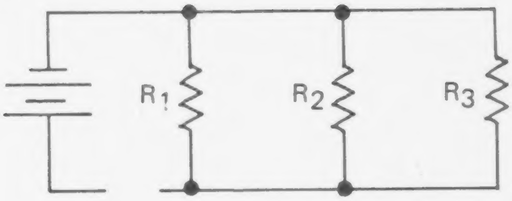
3. Which branch or branches will be knocked out of the circuit by the opens shown in the schematics below?

a.



______

b.



______

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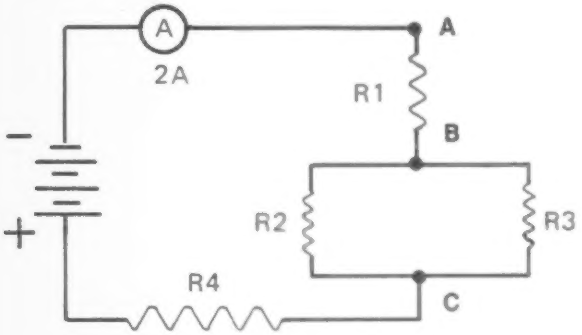
WORKBOOK SUPPLEMENT #15 - Trace Current Flow in Series-Parallel Circuits

The following problems will allow you to further develop your competency in analyzing series-parallel circuits and in tracing current flow.

1. Study the schematic and complete the statement below it.



Current will divide at Point ____, and come back together at Point ____.

2. From the circuit above, list the resistors:

in series ________.

in parallel ________.

3. Using the above circuit, select the correct statements about resistors 2 and 3. Write an "X" in the blanks preceding the correct statements.

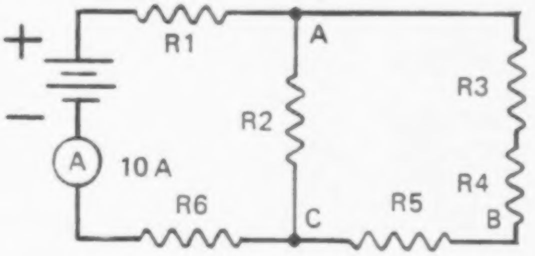
____a. They will carry a combined two amps of current

____b. They will each carry two amps of current

____c. They will carry a combined one amp of current

____d. They will each carry less than two amps of current

4. Study the schematic below. Write the correct answers in the blanks.



a. At what point does current divide? ______________________________

b. At what point does it come back together? ________________________

c. Does current divide more than once? ___________________________

5. List the three resistors in the circuit above that form a series string.

a. ____

b. ____

c. ____

6. List the resistors in the circuit above in series with the source.

a. ____

b. ____

7. In the circuit shown in problem 4, which of the statements below are correct? Write an "X" in the blanks preceding the correct statements.

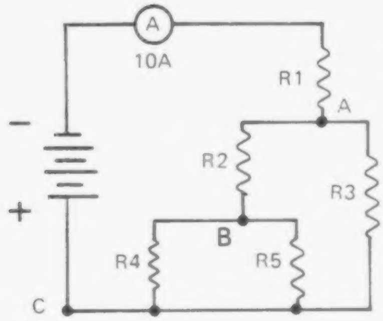
____a. R_2 is in parallel with R_3, R_4, and R_5

____b. Less than 10 amps will flow through R_2

____c. 10 amps will flow through R_6

____d. Less than 10 amps will flow through R_3, R_4, and R_5

8. Study the following schematic and answer the questions below it.



a. At what point does current first divide? ____________________

b. At what point does current next divide? ____________________

c. At what point does current all come back together? ____________

9. In the circuit shown in problem 8, check the pairs of resistors that are in parallel with each other. Write an "X" in the blank before each correct answer.

____a. R_1 and R_3

____b. R_2 and R_4

____c. R_2 and R_5

____d. R_4 and R_5

10. Answer the following questions in relation to the circuit shown in problem 8. Write the correct answer in the blanks.

a. How many resistors are directly in series with the rest of the circuit?____

b. Is the R_{eq} of R_4 and R_5 in series with R_2?____________

11. Using the circuit shown in problem 8, select the correct statements below. Write an "X" in the blank before each correct statement.

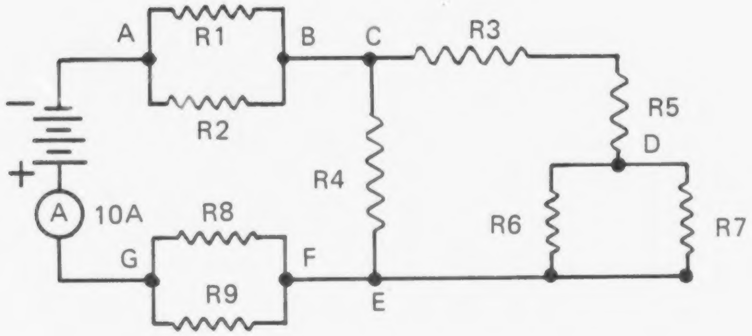
____a. $I_{R2} + I_{R3} = 10$ A

____b. An ammeter at Point C will measure 10 A

____c. Current through R_5 will be more than current through R_1

____d. $I_{R4} + I_{R5} = I_{R2}$

12. Study the following schematic and answer the questions below it.



a. Current first divides at which point? ______________________________

b. Current next divides at which point? ______________________________

c. Does current also divide at Point D? ______________________________

d. Does current also divide at Point F? ______________________________

e. How many resistors are in series with the source? __________________

f. Will there be a full 10 amps of current through R_7? ______________

g. Will there be a full 10 amps of current through R_4? ______________

h. Will there be a full 10 amps of current at Point G? ________________

i. Does total current go through R_2? ______________________________

j. Does a full 10 amps enter R_9? __________________________________

k. Will current be common through R_3 and R_5? ____________________

l. Does the full 10 amps of current enter Point D? ____________________

m. Name the two resistors in string.

1. ______________________________

2. ______________________________

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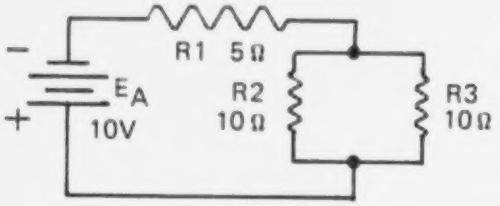
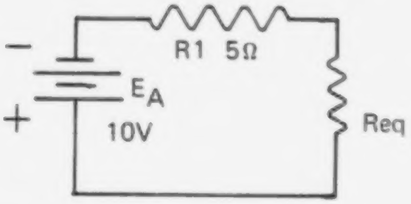
WORKBOOK SUPPLEMENT #16 - Perform Exercises in Circuit Reduction

The following problems will allow you to develop competency in circuit reduction. Redraw the following series-parallel circuits as series circuits. Write the correct answers in the blanks and redraw the circuits in the spaces provided. Below is an example of an original series-parallel circuit redrawn to a series circuit.

Original Circuit



Redrawn



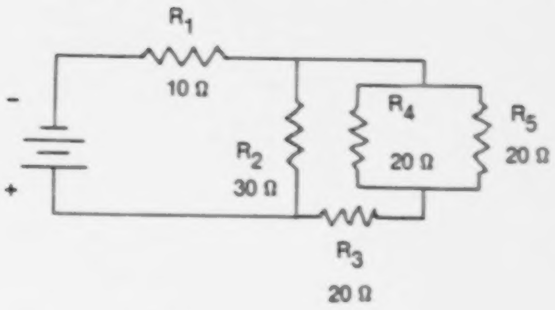
1. R_2 and R_3 in the original circuit have been combined into one resistor, which has become R_{eq} in the redrawn circuit. R_{eq} in the redrawn circuit will have the same resistance as R_2 and R_3 combined in the original circuit. In other words, R_{eq} in the redrawn circuit will be equal to R_{eq} of the original circuit.

   a. What is the resistance value of R_{eq} in the redrawn circuit above?

   ____

   b. Redraw the series-parallel circuit with just one resistor and show its value.

2. Using the redrawn schematic, show the new values.



3. You should now have two resistors in parallel. Redraw the circuit again, combining the parallel branches. Show the equivalent value of the parallel branch.

4. Your circuit should now be a series circuit with two resistors. Redraw the circuit once more, showing one equivalent resistor. Show values, including I_T, on the schematic.

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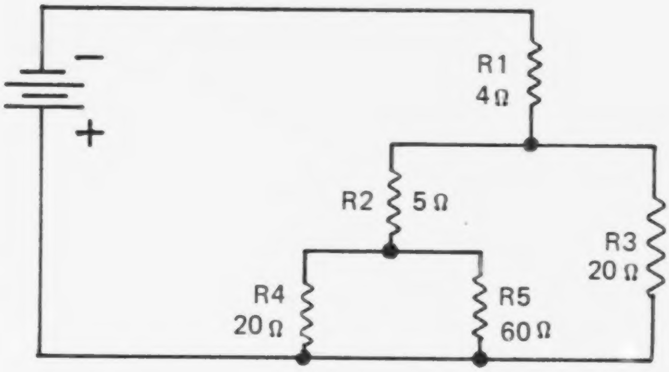
WORKBOOK SUPPLEMENT #17 - Solve for Total Resistance

This workbook supplement will allow you to develop competency in solving for total circuit resistance and circuit reduction in more complex circuits.

1. Study the circuit below. Trace current flow and determine which resistors are in parallel. Write the correct answer in the blank and redraw the circuit in the space provided.



a. First, find R_{eq} for R_4 and R_5 = ___________________________

b. Redraw the above circuit, showing R_4 and R_5 combined into one equivalent resistor. Show the values.

2. Note that R_2 and R_{eq} are now in series and are additive. Combine R_2 and R_{eq} into one equivalent resistor, R_{eq}. Redraw the circuit and show values.

3. Notice now that the new R_{eq} is in parallel with R_3. Find the next R_{eq} and redraw the circuit with appropriate values shown.

4. Redraw the final circuit showing one equivalent resistor, R_T.

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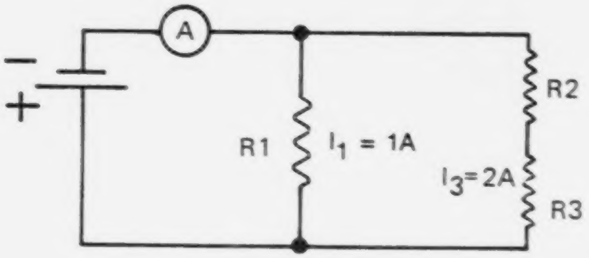
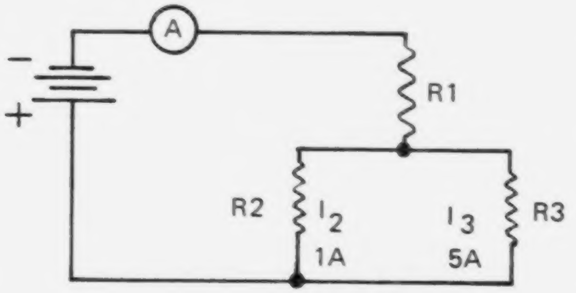
WORKBOOK SUPPLEMENT #18 - Solve for Total Current

The following problems will allow you to further develop your competency in reducing series-parallel circuits to solve for total current. Study the circuits below and write the correct total current in the blanks.

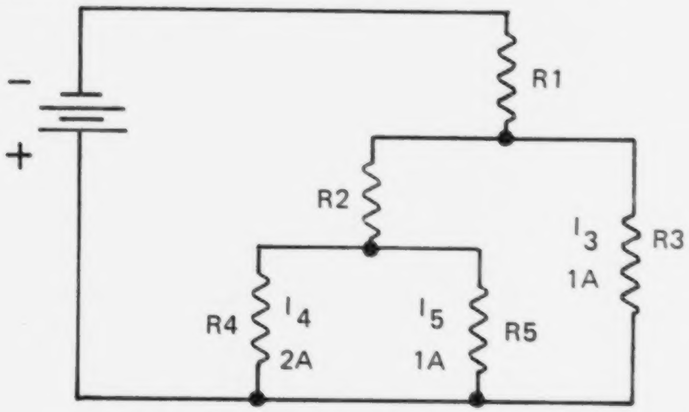
1. I_T = ________


A
−
+
R1
I_1 = 1A
R2
I_3= 2A
R3

2. I_T = ________


A
−
+
R1
R2
I_2
1A
I_3
5A
R3

3. I_T = ________


−
+
R1
R2
I_3
1A
R3
R4
I_4
2A
I_5
1A
R5

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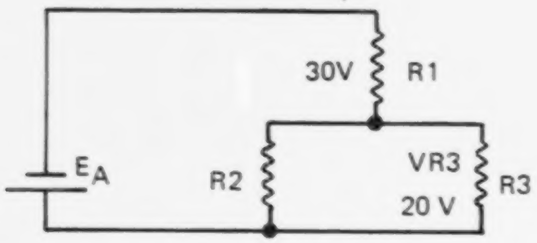
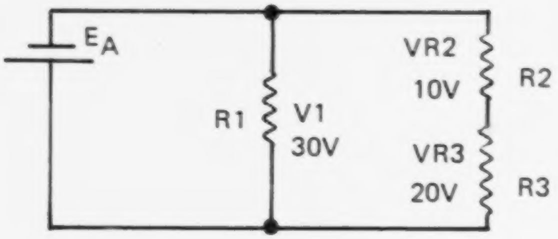
WORKBOOK SUPPLEMENT #19 - Solve for Total Voltage

The following problems will allow you to further develop your competency in reducing series-parallel circuits to solve for total voltage. Study the circuits below and write the correct total voltage in the blanks.

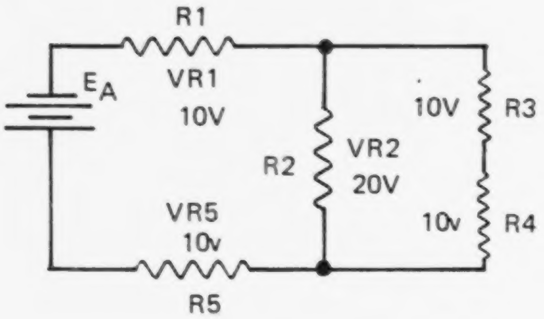
1. E_A = ________________________


30V
R1
EA
R2
VR3
20 V
R3

2. E_A = ________________________


EA
VR2
10V
R2
R1
V1
30V
VR3
20V
R3

3. E_A = ________________________


R1
EA
VR1
10V
10V
R3
R2
VR2
20V
VR5
10v
10v
R4
R5

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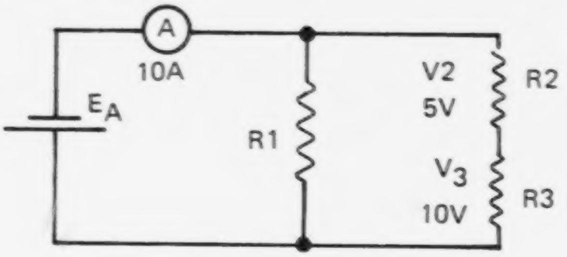
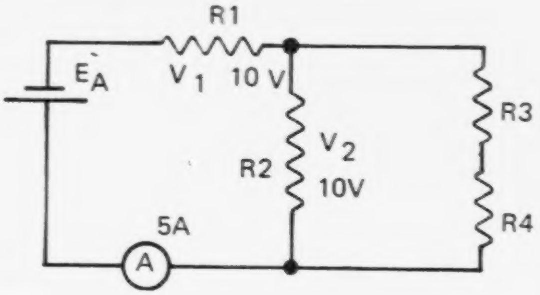
WORKBOOK SUPPLEMENT #20 - Solve for Total Power in Series-Parallel Circuits

The following problems will allow you to further develop competency in reducing series-parallel circuits to solve for total power. Study the circuits below and write the correct total power in the blanks.

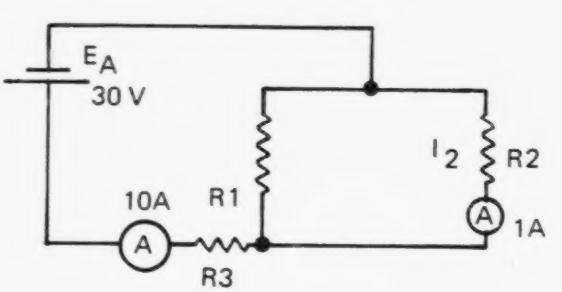
1. P_T = ______________________


A
10A
E_A
R1
V2
5V
R2
V_3
10V
R3

2. P_T = ______________________


R1
E_A
V_1 10 V
R3
R2
V_2
10V
R4
5A
A

3. P_T = ______________________


E_A
30 V
I_2
R2
10A
R1
A
1A
A
R3

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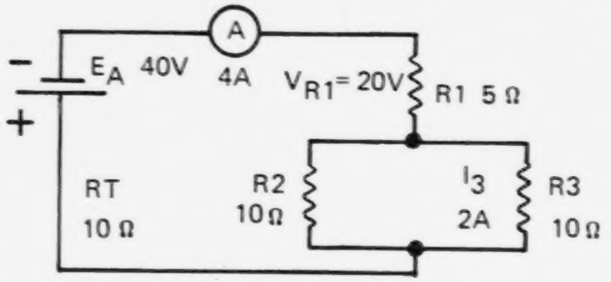
WORKBOOK SUPPLEMENT #21 - Solve for Branch Voltages and Currents in Series-Parallel Circuits

The following problems will allow you to develop your competency in solving for branch voltage drop and current through branches. Study the circuits below and answer the questions related to each circuit. Write the correct answers in the blanks.

1.

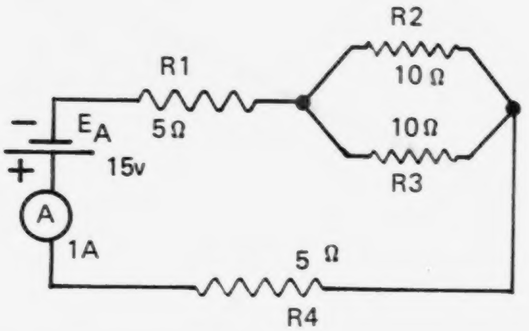

A
EA 40V
4A
VR1= 20V
R1 5 Ω
RT
10 Ω
R2
10 Ω
I3
2A
R3
10 Ω

a. In the circuit above, V_{R3} = ____________________

b. In the circuit above, V_{R2} = ____________________

c. In the circuit above, I_{R2} = ____________________

2. In the circuit below, the voltage drop across R_4 is __________


R2
10 Ω
R1
5 Ω
10 Ω
R3
EA
15v
A
1A
5 Ω
R4

3. In the circuit above, V_{R2} = ____________________

4. In the circuit above, I_{R3} = ____________________

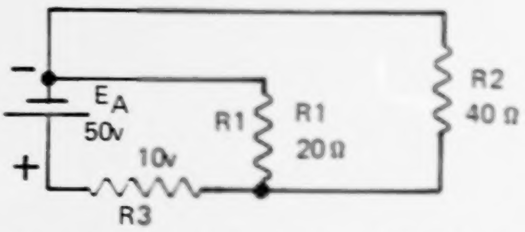
WORKBOOK SUPPLEMENT #21

5. Study the circuit below and solve for the following

a. V_{R2} = ____________________

b. I_{R1} = ____________________

c. I_{R2} = ____________________


−
E_A
50v
+
10v
R3
R1
R1
20 Ω
R2
40 Ω

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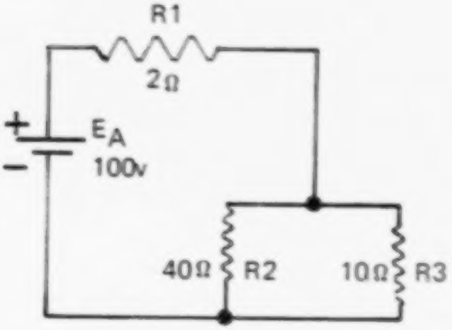
WORKBOOK SUPPLEMENT #22 - Solve for Multiple Values of Voltages and Currents

The following problems will allow you to futher develop your competency in solving for voltage and current in various portions of a series-parallel circuit. Solve for the quantities indicated and write the correct answers in the blanks.

1. Solve for quantities indicated.



a. R_{eq} of R_2, R_3 = ________

b. R_T = ____________

c. I_T = ____________

d. V_{R1} = ____________

e. V_{R2} = ____________

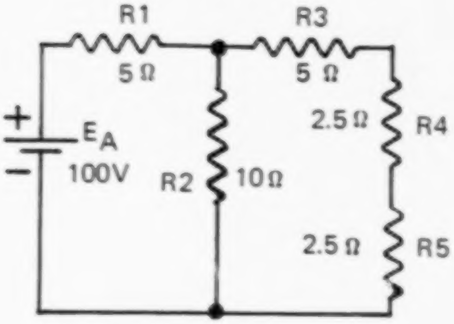
f. V_{R3} = ____________

g. I_{R1} = ____________

h. I_{R2} = ____________

i. I_{R3} = ____________

2. Solve for quantities indicated.



a. R_T = ____________

b. I_T = ____________

c. V_{R1} = ____________

d. V_{R2} = ____________

e. V_{R3} = ____________

f. V_{R4} = ____________

g. V_{R5} = ____________

h. I_{R2} = ____________

i. I_{R3} = ____________

j. I_{R4} = ____________

k. I_{R5} = ____________

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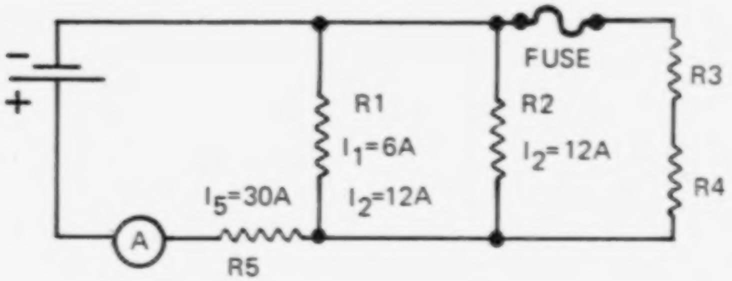
WORKBOOK SUPPLEMENT #23 - Analyze Opens and Shorts in Series-Parallel Circuits

The following problems will allow you to further develop your competency in analyzing the effects of opens and shorts in series-parallel circuits. Study the circuits provided for each question and write the correct answers in the blanks.

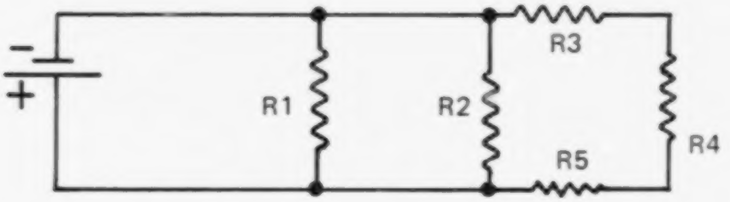
1. The fuse in the circuit below is rated at 10 amps. Analyze the circuit and answer the questions below it.



a. How many amps will try to flow through the fuse?________________

b. Will the fuse blow and create an open?_____________________

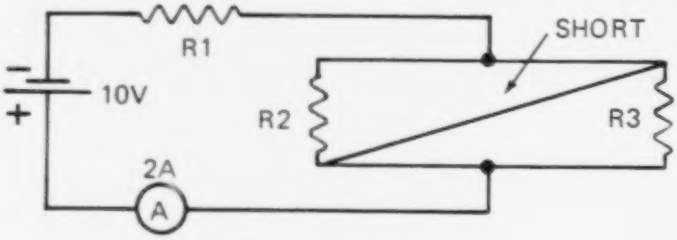
2. In the following circuit an open suddenly occurs between R_3 and R_4. Answer the following questions.



a. Total current will (increase, decrease, stay the same)?__________

b. I_{R3} will (increase, decrease, stay the same)?________________

3. In the shorted circuit below, the current flowing through



a. R_2 = ______________

b. R_3 = ______________

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WORKBOOK SUPPLEMENT #24 - Analyze Circuit Grounds and Voltage Polarity

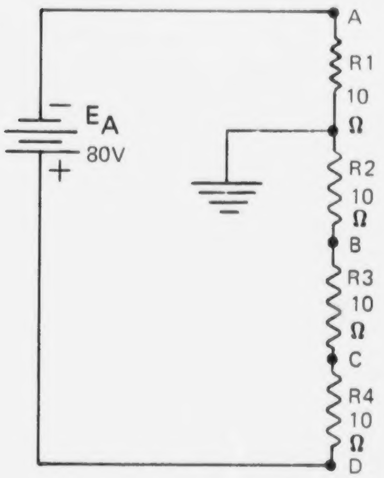
The following problems will allow you to develop competency in dealing with voltage dividers and grounds, especially with grounds not located at the power source. Study the circuit and indicate the polarity and voltages requested. Write the correct answers in the blanks.

1. a. The voltage between Point A and ground
   is ______________ (positive/negative)

   b. The voltage polarity between Point B and
   ground is _________ (positive/negative)

   c. The voltage polarity between Point C and
   ground is _______ (positive/negative)

   d. The voltage polarity between Point D and
   ground is _________ (positive/negative)



2. Study the circuit and answer the questions.

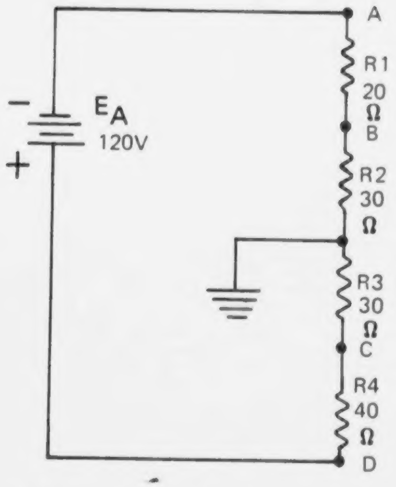
   a. The voltage and polarity from A to ground is ____________________________

   b. V_B (Point B to ground) is __________

   c. V_C (Point C to ground) is __________

   d. V_D (Point D to ground) is __________

   e. Voltage at Point D with respect to Point A is ____________________________



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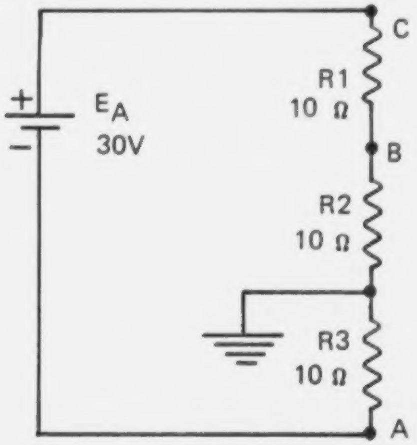
WORKBOOK SUPPLEMENT #25 - Analyze No-Load and Load Circuits

The following problems will allow you to develop competency in performing a circuit analysis between a no-load and a load circuit. Study the following circuits and answer the questions related to each circuit. Write the correct answers in the blanks.

1. Suppose you have been given a circuit with no-load condition. With respect to ground, what is the polarity and voltage at:

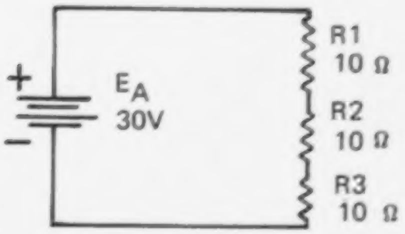


a. Point A________________________

b. Point B________________________

c. Point C________________________

2. Record the quantities in the circuit with no-load or ground connected. Fill in the blanks with the proper values.


+
−
E_A
30V
R1
10 Ω
R2
10 Ω
R3
10 Ω

a. R_T = ________________________________

b. I_T = ________________________________

c. V_{R1} = ________________________________

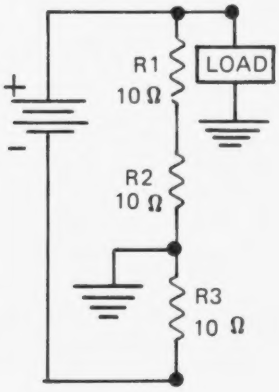
d. V_{R2} = ________________________________

e. V_{R3} = ________________________________

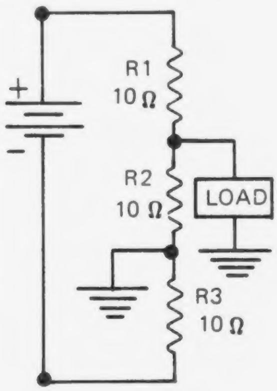
WORKBOOK SUPPLEMENT #25

3. Suppose that now you want to connect a load that needs negative volts to operate. Which of the following circuits shows the proper load connection? Select the correct circuit by writing an "X" in the blank before the correct answer.

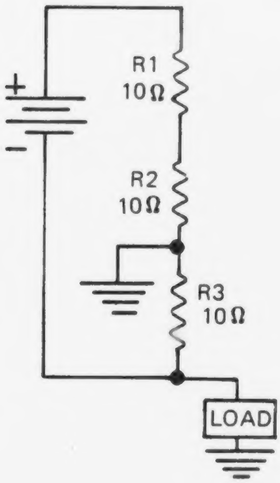
____a.


+
–
R1
10 Ω
LOAD
R2
10 Ω
R3
10 Ω

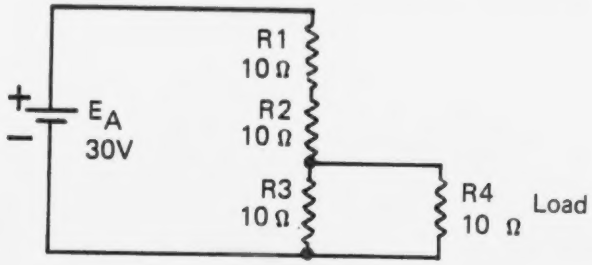
____b.


+
–
R1
10 Ω
R2
10 Ω
LOAD
R3
10 Ω

____c.


+
–
R1
10 Ω
R2
10 Ω
R3
10 Ω
LOAD

4. Connecting a load to the voltage divider gives a series-parallel circuit.



Notice that R_3 now becomes a resistor in parallel instead of in series.

The load you want to operate needs 10 volts. (Do you still have the necessary 10 volts when you connect the load across R_3?) By adding the load, you know that many quantities are going to change. Solve for quantities indicated. Write the correct answers in the blanks.

a. R_{eq} = ______________ (R_3 and R_4)

b. R_T = ______________

c. I_T = ______________

d. V_{R1} = ______________

e. V_{R2} = ______________

f. V_{R3} = ______________

5. Compare the quantities in your no-load circuit with the quantities in your load circuit, and complete the boxes below, using arrows to show increases or decreases.

	R_T	I_T	E_{R1}	E_{R2}	E_{R3}
Add R4					

6. State the voltage drop across R_4 ____________________________________

7. Will the load have 10 volts, connected as shown above? ______________

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ANSWERS TO WORKBOOK SUPPLEMENTS

Workbook Supplement #1

1. 1.29 A
2. 1.0 A
3. 2Ω
4. 12KΩ , 24V
5. a. 60 V
   b. 4Ω
   c. 6Ω
   d. 5Ω
   e. 15Ω
6. a. 20Ω
   b. 2 A
   c. 14 V
   d. 8 V
   e. 18 V

Workbook Supplement #2

1. 50 V
2. 100 V
3. 40 KV
4. 1000 V or 1 KV
5. 340 V
6. 100 V

Workbook Supplement #3

1. True
2. C
3. 25 V
4. 45 V
5. 30 V

Workbook Supplement #4

1. 6Ω
2. 5Ω
3. 3Ω

ANSWERS TO WORKBOOK SUPPLEMENTS

Workbook Supplement #5

1. 2 A
2. 500 mA or 0.5 A
3. 40 mA

Workbook Supplement #6

1. 2 A
2. 2 A
3. 1 A
4. 20 V
5. 2Ω
6. 20 V
7. 50 KΩ
8. 14.3 V

Workbook Supplement #7

1. 8Ω
2. 5 V
3.
   a. 15Ω
   b. 4 A
   c. 28 V
   d. 4 A
   e. 12 V
   f. 8 V
   g. 12 V
   h. 4 A
4.
   a. 5 mA
   b. 50 V
   c. 20 KΩ
   d. 100 V
   e. 5 mA
   f. 250 V
5.
   a. 50 KΩ
   b. 10 mA
   c. 10 mA
   d. 300 V
   e. 200 V
   f. 1 KV
6.
   a. 200 mA
   b. 5 KV
   c. 25 KΩ
   d. 5 KV
   e. 75 KΩ
   f. 200 mA
7. 100Ω
8. 100Ω

ANSWERS TO WORKBOOK SUPPLEMENTS

Workbook Supplement #8

1. 30 W

2. 20 W

3. 3 W

4. 40 W

5. 2 A

Workbook Supplement #9

1. a. 50 V
   b. 5 A
   c. 50 V
   d. 5 A
   e. 10 A

2. a. 5 A
   b. 100 V
   c. 5 A
   d. 10 A
   e. 100 V

3. a. 4 A
   b. 4 A
   c. 2 A
   d. 10 A
   e. 20 V
   f. 20 V
   g. 20 V

4. a. 60 V
   b. 60 V
   c. 60 V

5. a. 3 A
   b. 6 A
   c. 60 V
   d. 11 A

6. a. 4 A
   b. 8 A
   c. 20 V
   d. 20 V

7. 10 A

8. a. 2 mA
   b. 100 V
   c. 100 V
   d. 6 mA
   e. 100 V
   f. 100 V

ANSWERS TO WORKBOOK SUPPLEMENTS

Workbook Supplement #10

1. a. 20 Ω
   b. 30 Ω
   c. 12 Ω
   d. 12 Ω

2. 10 Ω

3. a. 10 Ω
   b. 30 Ω

4. 20 Ω

5. 20 Ω

6. 12 Ω

7. 20 Ω

8. 10 Ω

9. 6 Ω

10. 12 Ω

11. 5 Ω

12. 2 Ω

13. a. (3)
    b. (1)
    c. (2)

Workbook Supplement #11

1. 400 W

2. 2500 W

3. 5 W

Workbook Supplement #12

1. a. 100 V   d. 50 Ω
   b. 100 V   e. 50 Ω
   c. 16.7 Ω   f. 600 W

2. a. 5 Ω   d. 1 A
   b. 1 A   e. 1 A
   c. 3 A   f. 6 A

3. a. 3Ω
   b. 4 A
   c. 12 V
   d. 0.4 A or 400 mA

4. a. 20 V
   b. 5Ω
   c. 2 A
   d. 2 A
   e. 2Ω
   f. 200 W

Workbook Supplement #13

1.

E_A ↓	↓	→	↓	↓	↓	↓	↓	↓	↓	→	→	→
	I_T	R_T	P_T	I_{R1}	I_{R2}	I_{R3}	E_{R1}	E_{R2}	E_{R3}	R_1	R_2	R_3

2.

E_A ↑	↑	→	↑	↑	↑	↑	↑	↑	↑	→	→	→
	I_T	R_t	P_t	I_{R1}	I_{R2}	I_{R3}	E_{R1}	E_{R2}	E_{R3}	R_1	R_2	R_3

3.

Add R_4	↑	↓	→	↑	→	→	→	→	→	→	→	→	→
	I_t	R_t	E_t	P_t	R_1	R_2	R_3	E_{R1}	E_{R2}	E_{R3}	I_{R1}	I_{R2}	I_{R3}

4.

Remove R_3	↓	↑	→	↓	→	→	→	→	→	→
	I_T	R_T	E_T	P_T	E_{R1}	E_{R2}	R1	R2	I_{R1}	I_{R1}

5.

R_2 ↓	↑	↓	→	↑	→	→	→	→	→	→	↑	→
	I_T	R_T	E_T	P_T	R1	R3	E_{R1}	E_{R2}	E_{R3}	I_{R1}	IR2	I_{R3}

ANSWERS TO WORKBOOK SUPPLEMENTS

6. a.	E_A ↑	↑	→	▨	↑	↑	↑	↑	↑	↑	↑	→	→	→
b.	Remove R3	↓	↑	→	↓	→	→	▨	→	→	▨	→	→	▨
c.	R_1 ↑	↓	↑	→	↓	↓	→	→	→	→	→	▨	→	→
		I_t	R_t	E_t	P_t	I_{R1}	I_{R2}	I_{R3}	E_{R1}	E_{R2}	E_{R3}	R1	R2	R3

Workbook Supplement #14

1. a. 2
   b. 1
   c. 1
   d. 3

2. a. Decrease
   b. Increase
   c. Decrease

3. a. R_2
   b. R_1, R_2, R_3 or all branches

Workbook Supplement #15

1. Point B, Point C

2. In series - R_1 and R_4

   In parallel - R_2 and R_3

3. a, d

4. a. Point C
   b. Point A
   c. No

5. R_3, R_4, R_5

6. R_1, R_6

7. All are correct

8. a. Point A
   b. Point B
   c. Point C

9. d

10. a. One (R1)
    b. Yes

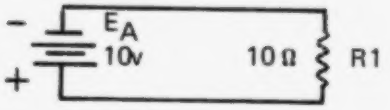
11. a, b, d

12. a. Point A
    b. Point C
    c. Yes
    d. Yes
    e. None
    f. No
    g. No
    h. Yes
    i. No
    j. No
    k. Yes
    l. No
    m. R_3 and R_5

Workbook Supplement #16

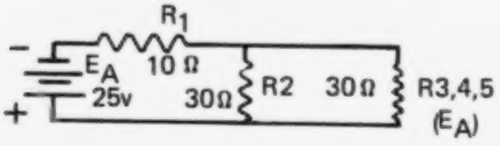
1. a. 5Ω

b.



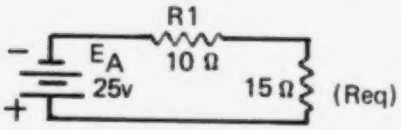
−
+
E_A
10v
10 Ω
R1

2.



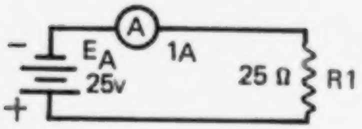
R_1
−
+
E_A
25v
10 Ω
30Ω
R2
30 Ω
R3,4,5
(E_A)

3.



R1
−
+
E_A
25v
10 Ω
15 Ω
(Req)

4.



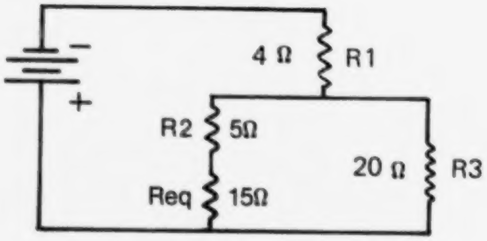
A
−
+
E_A
25v
1A
25 Ω
R1

ANSWERS TO WORKBOOK SUPPLEMENTS

Workbook Supplement #17

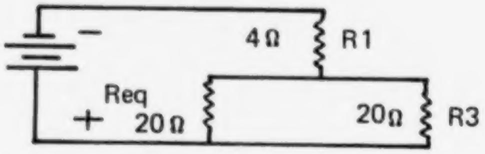
1. a. 15Ω

   b.



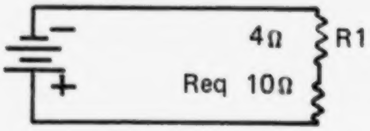
−
+
4 Ω
R1
R2
5Ω
20 Ω
R3
Req
15Ω

2.



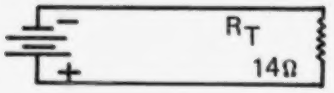
−
4Ω
R1
Req
+
20Ω
20Ω
R3

3.



−
4Ω
R1
+
Req 10Ω

4.



Workbook Supplement #18

1. 3 A
2. 6 A
3. 4 A

Workbook Supplement #19

1. 50 V
2. 30 V
3. 40 V

ANSWERS TO WORKBOOK SUPPLEMENTS

Workbook Supplement #20

1. 150 W

2. 100 W

3. 300 W

Workbook Supplement #21

1. a. 20 V
   b. 20 V
   c. 2 A

2. 5v

3. 5 V

4. 0.5 A or 500 mA

5. a. 40 V
   b. 2 A
   c. 1 A

Workbook Supplement #22

1. a. 8Ω
   b. 10Ω
   c. 10 A
   d. 20 V
   e. 80 V
   f. 80 V
   g. 10 A
   h. 2 A
   i. 8 A

2. a. 10Ω
   b. 10 A
   c. 50 V
   d. 50 V
   e. 25 V
   f. 12.5 V
   g. 12.5 V
   h. 5 A
   i. 5 A
   j. 5 A
   k. 5 A

Workbook Supplement #23

1. a. 12 A
   b. Yes

2. a. Decrease
   b. Decrease

3. a. Zero
   b. Zero

ANSWERS TO WORKBOOK SUPPLEMENTS

Workbook Supplement #24

1. a. 20 V negative
   b. 20 V positive
   c. 40 V positive
   d. 60 V positive

2. a. Negative 50 V
   b. Negative 30 V
   c. Positive 30 V
   d. Positive 70 V
   e. Positive 120 V

Workbook Supplement #25

1. a. Negative 10
   b. Positive 10 V
   c. Positive 20 V

2. a. 30Ω
   b. 1 A
   c. 10 V
   d. 10 V
   e. 10 V

3. c

4. a. 5Ω
   b. 25Ω
   c. 1.2 A
   d. 12 V
   e. 12 V
   f. 6 V

5.

	R_T	I_T	E_{R1}	E_{R2}	E_{R3}
Add R4	↓	↑	↑	↑	↓

6. 6 V

7. No

GENERAL
G105 AVIATION ELECTRICITY AND ELECTRONICS
DETERMINE THE RELATIONSHIP OF VOLTAGE, CURRENT,
RESISTANCE, AND POWER IN ELECTRICAL CIRCUITS
G105-A

THEORY TEST

1. Match terms related to electron theory to their correct definitions. Write the correct numbers in the blanks.

_____a. Most basic particle of negative electricity

_____b. Metric term measuring one thousand

_____c. Smallest particle of an element or compound that is capable of retaining the chemical identity

_____d. Flow of electrons from negative to positive in a circuit outside the source

_____e. Flow of electrons in one direction throughout a circuit

_____f. Smallest particle of an element

_____g. Uncharged particle in the nucleus of an atom

_____h. Metric prefix meaning one million

_____i. Electrons so loosely bound in the outer shells of some atoms that when an electromotive force is applied to the material, they are able to move from atom to atom

_____j. New entity formed by union of elements or parts

1. Direct current (DC)
2. Mega
3. Neutron
4. Compound
5. Electron
6. Molecule
7. Atom
8. Electron current flow
9. Free electrons
10. Kilo

THEORY TEST

_____k. Direct current that changes from zero to maximum, and then back to zero

_____l. Chemical substance that cannot be divided into simpler substances by chemical means

_____m. Atom that has either gained or lost an electron

_____n. Metric prefix meaning one one-thousandth

_____o. Center or core of an atom, consisting of positively charged protons and uncharged neutrons

_____p. Atom with a shortage of electrons

_____q. Metric term meaning one millionth

_____r. Flow of electrons in a circuit

_____s. Positively charged particles in the nucleus of an atom

_____t. Atom with an excess of electrons

11. Pulsating direct current
12. Proton
13. Ion
14. Element
15. Nucleus
16. Micro
17. Electron flow
18. Positive ion
19. Milli
20. Negative ion

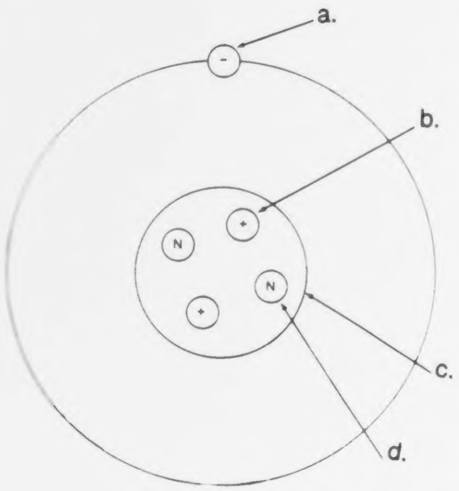
2. Label the parts of an atom. Write the correct answers in the blanks.

a. _____________

b. _____________

c. _____________

d. _____________



THEORY TEST

3. Describe electron flow in a conductor. Write the correct answers in the blanks.

   Electrons flow from the _______________ terminal to the __________________ terminal in a DC circuit.

4. List the five units of electrical measurement.

   a. Quantity: _________

   b. Flow: _________

   c. Opposition: __________

   d. Pressure: _________

   e. Power: _________

5. Match the metric prefixes to their correct multipliers. Write the correct numbers in the blanks.

Multiplier	Prefix
_____a. 1,000	1. Giga - g
_____b. 1,000,000	2. Mega - M
_____c. 0.000,000,001	3. Milli - m
_____d. 1,000,000,000	4. Kilo - k
_____e. 0.001	5. Nano - n
_____f. 0.000,001	6. Micro - μ (mu)

6. Multiply and divide the following numbers using the powers of ten. Rewrite the problems, indicating the powers of ten; and then solve the problems.

   a. 463,000,000 x 9,400,000 = (_____ x $10^{\_}$) x (_____ x $10^{\_}$)

   = __________ x $10^{\_}$

   b. 0.000,000,005 x 92 = (_____ x $10^{\_}$) x (_____ x $10^{\_}$)

   = __________ x $10^{\_}$

   c. 327,000,000,000 ÷ 545,000,000 = (_____ x $10^{\_}$) ÷ (_____ x $10^{\_}$)

   = __________ x $10^{\_}$

   d. 428,000,000 ÷ 0.000,000,004 = (_____ x $10^{\_}$) ÷ (_____ x $10^{\_}$)

   = __________ x $10^{\_}$

7. Discuss the relationship between static electricity and friction for an aircraft in flight.

THEORY TEST

8. Match terms related to magnets and electromagnets to their correct definitions. Write the correct numbers in the blanks.

_____a. A pointer mounted on an electromagnet in the field of a permanent magnet

_____b. Ferrous metal or alloy of ferrous metals, usually containing nickel and cobalt, in which the magnetic domains are aligned, and tend to remain aligned

_____c. Magnetism that remains in the core of an electromagnet after the magnetizing current no longer flows in the coil

_____d. Measure of magnetomotive force of an electromagnet; equivalent to the force produced when one ampere of current flows through one turn of the coil

_____e. One line of magnetic flux

_____f. Ability of a material to retain its magnetic properties

_____g. Ability to attract certain materials containing iron and to influence moving electrons

_____h. Measurement of flux density equal to one line of flux per square centimeter

_____i. Magnetizing force, measured in gilberts or ampere-turns

_____j. Space around a magnet or conductor where magnetic flux is found

_____k. Amount of magnetomotive force required to maintain one maxwell in a magnetic circuit having one unit of reluctance

1. Permanent magnet
2. Magnetism
3. D'Arsonval meter movement
4. Ampere-turn
5. Maxwell
6. Residual magnetism
7. Retentivity
8. Gauss
9. Magnetic field
10. Magnetomotive force (MMF)
11. Gilbert

THEORY TEST

____l. Magnetic lines of force

____m. Magnetic materials composed largely of iron

____n. Device or material that has the property of attracting or repelling other magnetic materials

____o. Opposition to magnetic flux

____p. Lines of magnetic force connecting the poles of a magnet

____q. Diminishing of oscillations of the pointer of an electrical meter by the generation of electromagnetic fields in the frame of the moving coil

____r. Magnetism developed by the magnetic field surrounding a current-carrying wire

____s. Magnet produced by electrical current flowing through a coil

____t. Conductor consisting of turns of wire in which the magnetic field around one turn cuts across the other turns, increasing the inductive effect of the wire

____u. Designation given to the ends of a magnet

____v. Property of an electrical device of having two different types of electrical charges

____w. Ability of a material to accept and concentrate lines of magnetic flux

____x. Material whose outer ring electrons are loosely bonded, so that a relatively low voltage will cause a flow of these electrons

____y. Invisible lines of magnetic force that are assumed to exist between the poles of a magnet

12. Ferromagnetic materials
13. Flux
14. Magnet
15. Reluctance
16. Electromagnetism
17. Electrodynamic damping
18. Electromagnet
19. Lines of flux
20. Polarity
21. Pole
22. Conductor
23. Permeability
24. Coil
25. Magnetic flux

9. Describe the magnetic lines of force of a permanent magnet.

____

____

____

____

10. Select true statements related to electromagnets. Place an "X" in the blank before each correct statement.

_____a. If a current-carrying conductor is grasped with the left hand, with the thumb pointing in the direction of electron flow (from negative to positive), the lines of force will encircle the conductor in the same direction as the fingers are pointing

_____b. By forming the conductor into a coil, the lines of flux can be concentrated, and the resulting coil will not have a north and a south pole

_____c. Movable-core electromagnets are called solenoids and are used in voltage regulators

_____d. If you grasp a coil with your left hand in such a way that your fingers wrap around the coil in the direction of electron flow, your thumb will point to the north pole of the electromagnet formed by the coil

_____e. The strength of an electromagnet is determined by the number of turns in the coil and by the amount of current flowing through it

THEORY TEST

11. Match terms related to DC electricity to their correct definitions. Write the correct numbers in the blanks.

_____a. Device that converts electrical energy into mechanical energy

_____b. Unit of electrical opposition equal to the resistance of a circuit in which an electromotive force of one volt will maintain a current of one ampere

_____c. Metal covers placed around electric and electronic devices to prevent the intrusion of external electrostatic and electromagnetic fields

_____d. Electrical charge which may be built up on a nonconductive surface by friction

_____e. Reference point for voltage measurement in an electrical circuit; to connect a part or component to the electrical ground

_____f. Material that has very few free electrons

_____g. Capacity for doing work

_____h. Voltage existing between two terminals or two points of differing potential

_____i. Product of force and the distance through which the force acts

_____j. Wire or electrical connection used to electrically ground a component or structure to an airframe

1. Shielding
2. Static electricity
3. Bonding jumper
4. Energy
5. Motor
6. Ground
7. Ohm (Ω)
8. Work
9. Dielectric
10. Potential difference (pd)

THEORY TEST

____k. Flow of electrons

____l. Force causing electrons to move through a conductor

____m. Basic unit of electrical power

____n. Unit of measure of electrical pressure; equivalent to the pressure required to force one ampere of current through one ohm of resistance

____o. Opposition to the flow of electrons offered by a device or material

____p. Law which establishes the relationship between current, voltage, and resistance in an electrical circuit

____q. Unintentional low-resistance path to ground for electrical current without its passing through the electrical load

____r. Standard unit of power used for mechanical measurement

____s. Term for electrical pressure or voltage

____t. Composed of electrons and protons that can be observed in the attracting and repelling of objects electrified by friction and in lightning and the aurora borealis

____u. Force causing flow of electrons, measured in volts

____v. One coulomb per second

11. Current (I)
12. Volt (V)
13. Watt (W)
14. Ohm's law
15. Resistance (R)
16. Ampere
17. Electromotive force (emf)
18. Potential
19. Voltage (E)
20. Horsepower (HP)
21. Electricity
22. Electrical short

12. List the five sources of electrical energy.

    a. ______________________________

    b. ______________________________

    c. ______________________________

    d. ______________________________

    e. ______________________________

13. State the relationship between voltage, current, and resistance using Ohm's law.

    ____

    ____

    ____

THEORY TEST

14. Match terms related to circuit elements to their correct definitions. Write the correct numbers in the blanks.

____a. Device designed to provide an electrical contact between a stationary conductor and a rotating element

____b. Energy-absorbing or energy-using device connected to a current

____c. Device made up of a number of individual cells, used to store electricity by converting it into chemical energy

____d. Mechanical device consisting of a conductor being turned within a magnetic field, used to produce electricity by electromagnetic induction

____e. Electrical circuit element used to provide a voltage drop by dissipating some of the electrical energy in the form of heat

____f. Manually operated device that opens and closes an electrical circuit

____g. Electromagnetic field and core necessary to open and close the the contacts of the relay

____h. Variable resistor having only two terminals

1. Resistor
2. Load
3. Battery
4. Rheostat
5. Brush
6. Switch
7. Generator
8. Solenoid

THEORY TEST

_____i. Complete path in which electrical current flows

_____j. Electrically operated remote switch whose contacts are closed or opened by a solenoid

_____k. Circuit-protecting device which opens the circuit in the case of excess current flow

_____l. Link of low-melting-point metal in an electrical circuit, which will melt and open the circuit when an excessive amount of current flows

_____m. Device used to store electrical energy in the form of electrostatic fields

_____n. Electrical power distribution point to which several circuits may be connected

_____o. Material or device used to prevent passage of heat, electricity, or sound from one medium to another

_____p. Variable resistor having both ends and its wiper in the circuit and used as a voltage divider; or instrument used for measuring differences in electrical potential by balancing the unknown voltage against a known variable voltage

9. Fuse
10. Relay
11. Insulator
12. Bus bar
13. Circuit breaker
14. Circuit
15. Potentiometer
16. Capacitor

15. List the three elements of a simple electrical circuit.

a. ____

b. ____

c. ____

16. Explain the physical characteristics that affect the resistance of a conductor.

    a. Resistivity - ______________________________

    ____

    ____

    b. Temperature - ______________________________

    ____

    c. Length - ______________________________

    ____

    ____

    d. Cross-sectional area - ______________________________

    ____

    ____

17. List the three main types of switches used in a circuit as control devices.

    a. ______________________________

    b. ______________________________

    c. ______________________________

18. List the two main types of circuit protective devices.

    a. ______________________________

    b. ______________________________

19. List the two types of circuit resistors.

    a. ______________________________

    b. ______________________________

THEORY TEST

20. Match terms related to circuit arrangements to their correct definition. Write the correct numbers in the blanks.

____a. Electrical current measuring device calibrated to read in milliamperes

____b. Electrical measuring instrument used to measure electron flow in amperes

____c. Electrical measuring instrument used to measure resistance by the amount of current which flows when a known voltage is applied across the unknown resistance

____d. Electrical measuring instrument used to measure electrical pressure or voltage

____e. Connecting fitting attached to the end of a wire, battery, or other component

____f. Electrical circuit that is not complete or continuous

____g. Accurately calibrated resistor placed in parallel with a meter movement for measuring current

____h. High-resistance measuring instrument incorporating a high-voltage DC generator in the instrument case

____i. Circuit in which there is only one path for electron flow from the source through the load back to the source

____j. Measure of the capacity of a battery; equivalent to the product of the amount of current flow and the time in which this amount can flow

____k. Two or more complete circuits connected to the same two power terminals

____l. Strip of insulating material containing terminal posts to which aircraft wiring is attached

1. Terminal
2. Ammeter
3. Ohmmeter
4. Milliammeter
5. Voltmeter
6. Open circuit
7. Terminal strip
8. Series circuit
9. Ampere-hour
10. Shunt
11. Parallel circuits
12. Megohmmeter

THEORY TEST

21. Define the three types of circuits.

   a. Series - ______________________________

   ____

   b. Parallel - ______________________________

   ____

   c. Complex - ______________________________

   ____

22. State the principle of Kirchhoff's voltage law.

   ____

   ____

   ____

23. State the principle of Kirchhoff's current law.

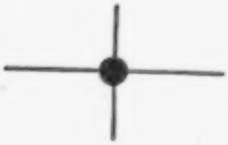
   ____

   ____

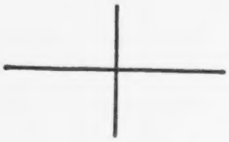
   ____

THEORY TEST

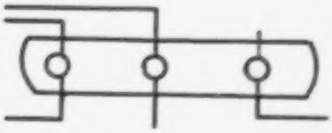
24. Identify basic electrical symbols related to DC electricity. Write the correct names of the symbols in the blanks.



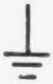
a. ________________________



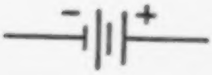
b. ________________________



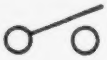
c. ________________________



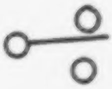
d. ________________________



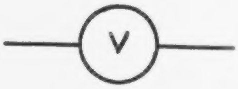
e. ________________________



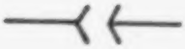
f. ________________________



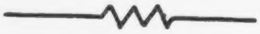
g. ________________________



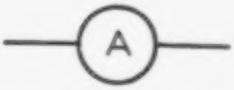
h. ________________________



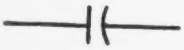
i. ________________________



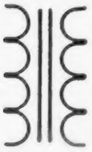
j. ________________________



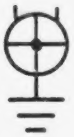
k. ________________________



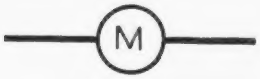
l. ________________________



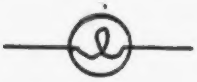
m. ____________________



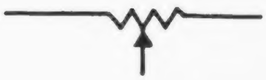
n. ____________________



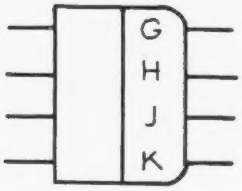
o. ____________________



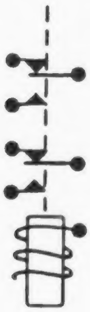
p. ____________________



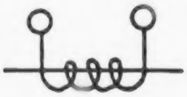
q. ____________________



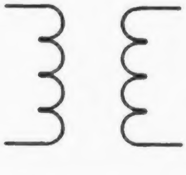
r. ____________________



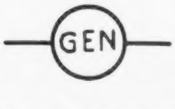
s. ____________________



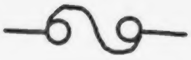
t. ____________________



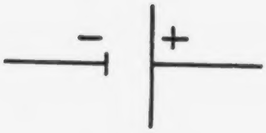
u. ____________________



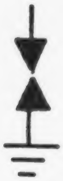
v. ____________________



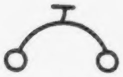
w. ________________________



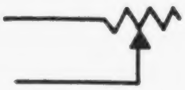
x. ________________________



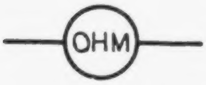
y. ________________________



z. ________________________



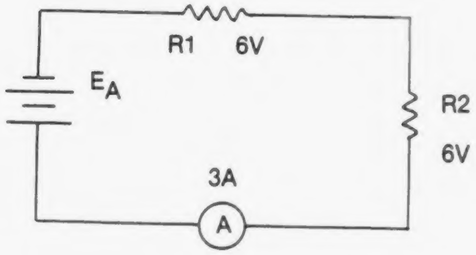
aa. ________________________



bb. ________________________

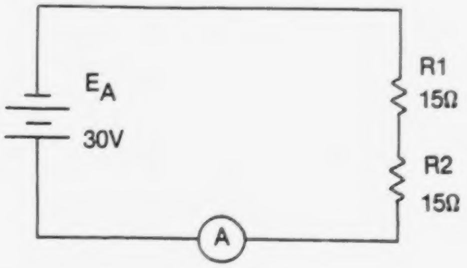
25. Solve the following problem using the relationship between current, voltage, and resistance in a series circuit to find the resistance of R_2. Write the correct answer in the blank.

R_2 = ______



26. Compute the power dissipated in a resistive circuit. Write the correct answer in the blank.

P_T = _______



27. Distinguish between the characteristics of a series circuit and a parallel circuit. Write an "S" in the blanks preceding series circuit characteristics and a "P" in the blanks preceding parallel circuit characteristics.

_____a. There is only one path for the electrons to follow from the source, through the load back to the source.

_____b. The current is the same wherever it is measured in the circuit.

_____c. There is more than one path for the electrons to follow from the source, through part of the load, back to the source.

_____d. The total power dissipated in the circuit is the sum of the power dissipated in each of the individual load resistances.

_____e. The voltage is the same across any of the paths.

_____f. The total resistance of the circuit is the sum of the individual load resistances.

_____g. The current through each path is inversely proportional to the resistance of the path.

_____h. The sum of all of the voltage drops equals the source voltage.

_____i. The total current is the sum of the current flowing through each of the individual paths.

_____j. The total resistance of the circuit is less than the resistance of any of the paths.

_____k. The total power dissipated in the circuit is the sum of the power dissipated in each of the individual load resistances.

28. Solve the following problem using the relationship between current, voltage, and resistance in a parallel circuit. Write the correct answers in the blanks.

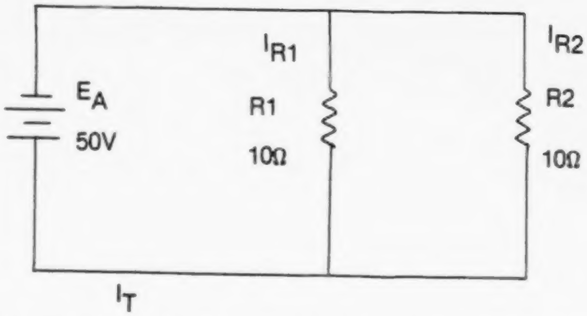
a. E_{R1} = ______

b. I_{R1} = ______

c. E_{R2} = ______

d. I_{R2} = ______

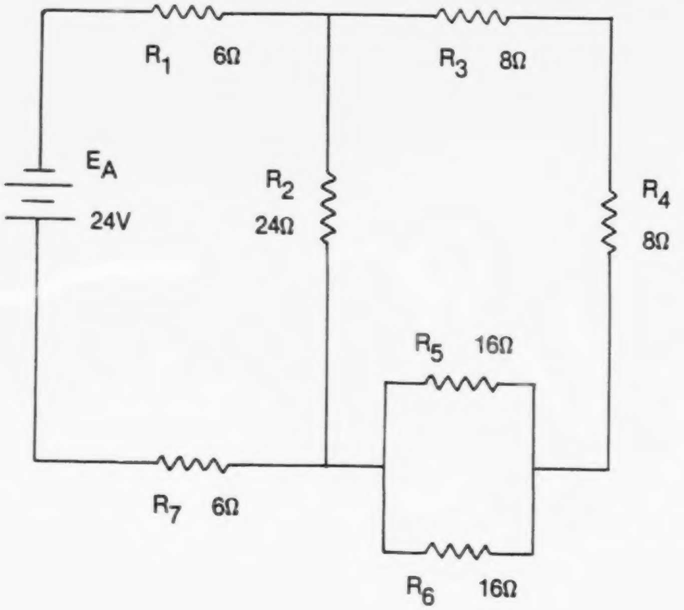
e. I_T = ______



29. Solve the following problem using the relationship between current, voltage, resistance, and power in a parallel circuit to find the total power. Write the correct answer in the blank.

P_T = ______

30. Solve the following problem using the relationship between current, voltage, resistance, and power in a series-parallel circuit to find the missing values. Write the correct answers in the blanks.


R1 6Ω
R3 8Ω
EA
24V
R2
24Ω
R4
8Ω
R5 16Ω
R7 6Ω
R6 16Ω

a. E_1 = ________

I_1 = ________

P_1 = ________

b. E_2 = ________

I_2 = ________

P_2 = ________

c. E_3 = ________

I_3 = ________

P_3 = ________

d. E_4 = ________

I_4 = ________

P_4 = ________

e. E_5 = ________

I_5 = ________

P_5 = ________

f. E_6 = ________

I_6 = ________

P_6 = ________

g. E_7 = ________

I_7 = ________

P_7 = ________

h. E_T = ________

I_T = ________

P_T = ________

GENERAL
G105 AVIATION ELECTRICITY AND ELECTRONICS
DETERMINE THE RELATIONSHIP OF VOLTAGE, CURRENT, AND RESISTANCE IN ELECTRICAL CIRCUITS
G105-A

ANSWERS TO THEORY TEST

1. a. 5
   b. 10
   c. 6
   d. 8
   e. 1
   f. 7
   g. 3
   h. 2
   i. 9
   j. 4
   k. 11
   l. 14
   m. 13
   n. 19
   o. 15
   p. 18
   q. 16
   r. 17
   s. 12
   t. 20

2. a. Electron
   b. Proton
   c. Nucleus
   d. Neutron

3. Electrons flow from the negative terminal to the positive terminal in a DC circuit

4. a. Coulomb
   b. Ampere
   c. Ohm
   d. Volt
   e. Watt

5. a. 4
   b. 2
   c. 5
   d. 1
   e. 3
   f. 6

6. a. $4.63 \times 10^8 \times 9.4 \times 10^6 = 4.35223 \times 10^{15}$

   b. $5.0 \times 10^{-9} \times 9.2 \times 10^1 = 4.6 \times 10^{-7}$

   c. $3.27 \times 10^{11} \div 5.45 \times 10^8 = 6.0 \times 10^2$

   d. $4.28 \times 10^8 \div 4.0 \times 10^{-9} = 1.07 \times 10^{17}$

7. Friction between the air and the surface builds up a large static charge which cannot readily bleed off upon landing

ANSWERS TO THEORY TEST

8. a. 3
b. 1
c. 6
d. 4
e. 5
f. 7
g. 2
h. 8
i. 10
j. 9
k. 11
l. 13
m. 12
n. 14
o. 15
p. 19
q. 17
r. 16
s. 18
t. 24
u. 21
v. 20
w. 23
x. 22
y. 25

9. Lines of magnetic force form complete loops, leaving the magnet at its north pole and returning at its south pole

10. a, d, e

11. a. 5
b. 7
c. 1
d. 2
e. 6
f. 9
g. 4
h. 10
i. 8
j. 3
k. 11
l. 17
m. 13
n. 12
o. 15
p. 14
q. 22
r. 20
s. 18
t. 21
u. 19
v. 16

12. a. Electromagnetic induction
b. Chemical
c. Thermal (heat)
d. Pressure
e. Light

13. E = IR. Current in a circuit is directly proportional to voltage and inversely proportional to resistance

ANSWERS TO THEORY TEST

14. a. 5
    b. 2
    c. 3
    d. 7
    e. 1
    f. 6
    g. 8
    h. 4
    i. 14
    j. 10
    k. 13
    l. 9
    m. 16
    n. 12
    o. 11
    p. 15

15. a. Source of electrical energy
    b. Load
    c. Conductors

16. a. Resistivity--The amount of inherent resistance a conductor has

    b. Temperature--Affects the resistivity of a conductor

    c. Length--The resistance of a conductor varies directly as its length

    d. Cross-sectional area--The resistance of a conductor varies inversely as its cross-sectional area

17. a. Toggle or rocker switches
    b. Wafer switches
    c. Precision switches

18. a. Fuse
    b. Circuit breaker

19. a. Fixed
    b. Variable

20. a. 4
    b. 2
    c. 3
    d. 5
    e. 1
    f. 6
    g. 10
    h. 12
    i. 8
    j. 9
    k. 11
    l. 7

21. Definition should include the following

    a. Series--Current follows one path
    b. Parallel--All load components are connected directly across source
    c. Complex--Combination of series and parallel connections

22. Sum of the voltage drops around any circuit is the sum of the voltage applied

ANSWERS TO THEORY TEST

23. Current entering a point or junction is equal to the current leaving that junction

24. a. Permanent connection
    b. No connection
    c. Bus
    d. Ground
    e. Battery
    f. Single-pole, single-throw switch (SPST switch)
    g. Single-pole, double-throw switch (SPDT switch)
    h. Voltmeter
    i. Single conductor connector
    j. Resistor
    k. Ammeter
    l. Fixed capacitor
    m. Iron core transformer
    n. Spark igniter
    o. Motor
    p. Lamp or bulb
    q. Potentiometer
    r. Four conductor connector
    s. Relay coil with contacts
    t. Solenoid
    u. Air core transformer
    v. Generator
    w. Fuse
    x. One cell
    y. Spark plug
    z. Circuit breaker
    aa. Rheostat
    bb. Ohmmeter

25. $R_2 = 2\Omega$

26. $P_T = 30$ W

27. a. S
    b. S
    c. P
    d. S
    e. P
    f. S
    h. P
    h. S
    i. P
    j. P
    k. P

ANSWERS TO THEORY TEST

28. a. 50 V
    b. 5 A
    c. 50 V
    d. 5 A
    e. 10 A

29. P_T = 150 W

30. a. $E_1 = 6$ V
    $I_1 = 1$ A
    $P_1 = 6$ W

    b. $E_2 = 12$ V
    $I_2 = 0.5$ A
    $P_2 = 6$ W

    c. $E_3 = 4$ V
    $I_3 = 0.5$ A
    $P_3 = 2$ W

    d. $E_4 = 4$ V
    $I_4 = 0.5$ A
    $P_4 = 2$ W

    e. $E_5 = 4$ V
    $I_5 = 0.25$ A
    $P_5 = 1$ W

    f. $E_6 = 4$ V
    $I_6 = 0.25$ A
    $P_6 = 1$ W

    g. $E_7 = 6$ V
    $I_7 = 1$ A
    $P_7 = 6$ W

    h. $R_T = 24\,\Omega$
    $I_T = 1$ A
    $P_T = 24$ W

MODULE OF INSTRUCTION
FOR
AVIATION MAINTENANCE TECHNOLOGY

GENERAL
G105 AVIATION ELECTRICITY AND ELECTRONICS
COMPUTE AND MEASURE CAPACITANCE AND INDUCTANCE
G105-B

GENERAL
G105 AVIATION ELECTRICITY AND ELECTRONICS
COMPUTE AND MEASURE CAPACITANCE AND INDUCTANCE
G105-B

MODULE CONTENTS

A. Introduction and Module Objective

B. Specific Objectives

C. Instructor's Module Implementation Guide

D. Technical Information Supplements

  1. Technical Information Supplement #1 - Terms and Definitions
  2. Technical Information Supplement #2 - AC Electrical Symbols and Abbreviations

E. Transparency Masters

  1. TM #1 - The Left Hand Generator Rule
  2. TM #2 - Simple AC Generator
  3. TM #3 - AC Generation
  4. TM #4 - Principal Generator Parts
  5. TM #5 - Principal Generator Parts (Continued)
  6. TM #6 - Generator Rotor With Shaft-Driven Exciter
  7. TM #7 - AC Waveform Components
  8. TM #8 - Values of Sine Wave Alternating Current
  9. TM #9 - Values of Sine Wave Alternating Current (Continued)
  10. TM #10 - Values of Sine Wave Alternating Current (Continued)
  11. TM #11 - Factors That Determine Inductance
  12. TM #12 - Factors That Determine Inductance (Continued)
  13. TM #13 - Inductor Build-up
  14. TM #14 - Capacitor Construction
  15. TM #15 - Plate Area

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16. TM #16 - Plate Distance

17. TM #17 - Effect of the Dielectric

18 TM #18 - Electric Field Effect on Capacitors

19. TM #19 - Capacitor Specifications

F. Workbook Supplements

1. Workbook Supplement #1 - Convert from One Voltage Measurement to Another and Label Waveform Components

2. Workbook Supplement #2 - Determine Current, Resistance, Voltage, and Power in Resistive AC Circuits

3. Workbook Supplement #3 - Determine Values in R-L Circuits

4. Workbook Supplement #4 - Determine Values in R-C Circuits

5. Workbook Supplement #5 - Determine Values in R-C-L Circuits

G. Answers to Workbook Supplements

H. Theory Test

I. Answers to Theory Test

GENERAL
G105 AVIATION ELECTRICITY AND ELECTRONICS
COMPUTE AND MEASURE CAPACITANCE AND INDUCTANCE
G105-B

INTRODUCTION

AC electricity is becoming more prevalent in aircraft applications. It has many advantages over DC power: Lighter wiring can be used to transmit the same amount of power, power can be controlled using non-power-consuming components, and AC motors have no brushes and, therefore, do not arc at high altitudes. A thorough knowledge of the relationship between resistance, capacitance, inductance, and impedance is necessary for the aviation maintenance technician to troubleshoot these circuits.

MODULE OBJECTIVE

After completion of this module, you will be able to identify AC electrical symbols, state the relationship between peak-to-peak and rms voltage, and solve problems related to AC electricity. You will demonstrate this knowledge by completing the procedures outlined in the workbook assignments and by scoring a minimum of 85 percent on the module theory test.

GENERAL
G105 AVIATION ELECTRICITY AND ELECTRONICS
COMPUTE AND MEASURE CAPACITANCE AND INDUCTANCE
G105-B

SPECIFIC OBJECTIVES

After completion of this module, you will be able to:

1.	Match terms related to AC electricity to their correct definitions. (1)	Technical Supplement #1
2.	State the relationship between peak, peak-to-peak, average, and rms voltage. (2)	EA-ITP-G 3:III:10 EA-ITP-GW 3:1-3 Workbook Supplement #1
3.	Determine current, resistance, voltage, and power in a resistive AC circuit. (3)	EA-ITP-G 3:IV:11 Workbook Supplement #2
4.	Identify basic AC electrical symbols. (2)	Technical Supplement #2
5.	Select true statements related to the principle of operation of an inductor. (1)	EA-ITP-G 3:V:12-20 EA-ITP-GW 3:3-5
6.	Determine current, resistance, inductance, inductive reactance, impedance, power factor, phase angle, true power, and apparent power in R-L circuits. (3)	EA-ITP-G 3:VII:31-32 Workbook Supplement #3
7.	Determine values of voltage and current in the secondary windings of a transformer. (2)	EA-ITP-G 3:V:18-20 EA-ITP-GW 3:5-6
8.	Select true statements related to the principle of operation of a capacitor. (1)	EA-ITP-G 3:V:21-30 EA-ITP-GW 3:6-8
9.	Determine current, resistance, capacitance, capacitive reactance, impedance, power factor, phase angle, true power, and apparent power in R-C circuits. (3)	EA-ITP-G 3:VII:33-34 Workbook Supplement #4
10.	Determine current, resistance, capacitance, capacitive reactance, power factor, phase angle, true power, apparent power, impedance, inductance, and inductive reactance in R-C-L circuits. (3)	EA-ITP-G 3:VII:34-35 EA-ITP-GW 3:9-12 Workbook Supplement #5
11.	Determine resonant frequency in an R-C-L circuit when inductance and capacitance are known. (3)	EA-ITP-G 3:IX:39-41 EA-ITP-GW 3:14

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G105-B

INSTRUCTOR'S MODULE IMPLEMENTATION GUIDE

I. Order materials to supplement module--Videotapes:

A. Principles of Alternating Current, ITP-G3, Program 1.

B. Inductance, Capacitance, and Impedance, ITP-G3, Program 2.

(NOTE: These videotapes are available from Aviation Maintenance Publishers, Inc., P.O. Box 36, 1000 College View Drive, Riverton, Wyoming 82501.)

II. Implementation Suggestions

Estimated Teaching Time		Theory	Lab
Objective 1	Discuss the terms related to AC electricity and their definitions as given in Technical Information Supplement #1. Show videotape Principles of Alternating Current, ITP-G3, Program 1.		
Objective 2	Explain the relationship between peak, peak-to-peak, average, and rms voltage. Show Transparency Masters #1-#10. Have students complete Workbook Supplement #1 and EA-ITP-GW 3:1-3.		
Objective 3	Discuss the determination of values for current, resistance voltage, and power in a resistive AC circuit. Have students complete Workbook Supplement #2.		
Objective 4	Discuss AC electrical symbols. Have students refer to Technical Information Supplement #2.		
Objective 5	Explain how inductors work, and the use of formulas for inductive loads in series and parallel circuits. Show Transparency Masters #11-#13. Have students complete EA-ITP-GW 3:3-5.		

INSTRUCTOR'S MODULE IMPLEMENTATION GUIDE

Estimated Teaching Time		Theory	Lab
Objective 6	Discuss the determination of inductive reactance using known values for frequency and inductance. Show how impedance is determined using known values for resistance and inductive reactance. Discuss the determination of phase angle relationships in R-L circuits. Explain how to determine current, resistance, inductance, power factor, apparent power, and true power in R-L circuits. Have students complete Workbook Supplement #3.		
Objective 7	Explain the principle of operation of transformers including the relationship between primary and secondary voltages. Show students how to determine values for voltage and current in the secondary windings of a transformer. Have students complete EA-ITP-GW 3:5-6.		
Objective 8	Explain the principle of operation of a capacitor, and discuss the formulas for capacitive loads in series and parallel. Show Transparency Masters #14-#19. Have students complete EA-ITP-GW 3:6-8.		
Objective 9	Explain how to determine capacitive reactance using known values for frequency and capacitance. Compare and contrast capacitive calculations with those for inductance. Discuss the determination of impedance when values for resistance and capacitive reactance are known. Compare the phase angle relationships in R-C circuits with those in R-L circuits. Discuss the determination of current, resistance, capacitance, capacitive reactance, power factor, phase angle, true power and apparent power in R-C circuits. Have students complete Workbook Supplement #4. Show videotape Inductance, Capacitance, and Impedance, ITP-G3, Program 2.		

INSTRUCTOR'S MODULE IMPLEMENTATION GUIDE

Estimated Teaching Time		Theory	Lab
Objective 10	Show students how to determine current, resistance, capacitance, capacitive reactance, power factor, phase angle, true power, apparent power, impedance, inductance, and inductive reactance in R-C-L circuits. Have students complete Workbook Supplement #5 and EA-ITP-GW 3:9-12		
Objective 11	Explain resonance and discuss the determination of resonant frequency in an R-C-L circuit using known values for capacitance and inductance. Have students complete EA-ITP-GW 3:14.		

GENERAL
G105 AVIATION ELECTRICITY AND ELECTRONICS
COMPUTE AND MEASURE CAPACITANCE AND INDUCTANCE
G105-B

TECHNICAL INFORMATION SUPPLEMENT #1 - Terms and Definitions

A. Alternating current - Electric current which periodically changes in direction and constantly changes in magnitude

B. Alternation - Part of an AC cycle during which current is flowing in one direction; one half of a cycle

C. Amplitude - Maximum instantaneous value of an alternating current or voltage, measured in either the positive or negative direction

D. Apparent power - Product of voltage and amperage in an AC circuit, with no consideration of the power factor for the phase angle

E. Capacitance - Ability of a capacitor to oppose any change in voltage, or ability of an electrical device to store a charge of electricity

F. Capacitive reactance - Opposition to the flow of alternating current offered by a capacitor

G. Capacitor - Device used to store an electrical charge in a circuit, composed of two or more sets of plates, separated by a nonconducting material called a dielectric

H. Coil - Winding of wire designed for use in a circuit to produce an electromagnetic field or to produce inductance

I. Cycle - One complete positive and one complete negative alternation of alternating current or voltage

J. Effective value - Value of AC which will give an equal heating effect as DC, equal to 0.707 times the peak value

K. Electrostatic field - Force in space which exerts an equivalent force on an electrical charge within its region of influence

L. Electrostatic induction - Process of charging an object electrically by placing it in an electric field

M. Farad - Basic unit of measure of capacitance; ability of a capacitor to store one coulomb of electricity for each volt applied across its plates

N. Frequency - Number of complete cycles per second

O. Frequency meter - Instrument for measuring the cycles per second of an alternating current or voltage

TECHNICAL INFORMATION SUPPLEMENT #1

P. Full-wave rectifier - Rectifier which uses both the positive and negative alternations of AC to produce pulsating direct current

Q. Henry - Basic unit of measure for inductance

R. Horsepower - Common unit of mechanical power, equivalent of raising 33,000 pounds one foot in one minute, or 550 pounds one foot in one second

S. Impedance - Total opposition to alternating current when the opposition consists of any combination of resistance, inductive reactance, and capacitive reactance, measured in ohms

T. Inductance - Property of a coil to oppose any change in current flow

U. Inductive reactance - Opposition to the flow of alternating current caused by the inductance of a circuit

V. Inductor - Device which causes inductance

W. In-phase - Condition that exists when two waves of the same frequency pass through their maximum and minimum values at the same time

X. Kilovolt ampere - Unit of measure used to designate apparent power

Y. Kilovolt ampere reactance - Unit of measure used to designate reactive power

Z. Kilowatt - Unit of measure used to designate true power

AA. Lead - Amount one wave is ahead another in time, expressed in electrical degrees

BB. Lag - Amount one wave is behind another in time, expressed in electrical degrees

CC. Mutual induction - Circuit property existing when the position of two coils causes the magnetic lines of force from one coil to link with the turns of the other coil and induce an EMF

DD. Peak value - Greatest value reached during an alternation

EE. Phase - Time relationship between alternating voltages or currents

FF. Phase angle - Time in electrical degrees by which one wave leads or lags another

GG. Power factor - Ratio of true power to apparent power of an AC circuit

HH. Pulsating direct current - Current which changes in amplitude but flows in only one direction

TECHNICAL INFORMATION SUPPLEMENT #1

II. R-C circuit - Circuit that contains capacitance and resistance

JJ. R-C-L circuit - Circuit that contains resistance, capacitance, and inductance

KK. Reactance - Opposition to the flow of alternating current offered by inductance, capacitance, or both

LL. Reactive load - Load in which the current is not in phase with the applied voltage; a capacitive or an inductive load

MM. Reactor - Component which introduces reactance into a circuit

EXAMPLE: A coil or a capacitor

NN. Rectifier - Device which changes alternating current into direct current

OO. R-L circuit - Circuit that contains resistance and inductance

PP. Sine wave - Graph of one cycle of alternating current or voltage

QQ. Single-phase - Circuit that is energized by a single alternating current

RR. Three-phase - Alternating current system in which there are three separate voltages and currents at one time

SS. True power - Power consumed by resistance in a circuit

TT. Vector - Line used to represent both direction and magnitude

UU. Volt - Basic unit of measure of electrical pressure; the EMF required to cause one ampere of current to flow through one ohm of resistance

VV. Volt-amp - Produce of current and voltage in an AC circuit

WW. Resonant circuit - Circuit in which current and voltage are in-phase, capacitive reactance is equal to inductive reactance, true power is equal to apparent power, and phase angle is zero.

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TECHNICAL INFORMATION SUPPLEMENT #2 - AC Electrical Symbols and Abbreviations

A. Z - Impedance

B. X - Reactance

C. X_C - Capacitive reactance

D. X_L - Inductive reactance

E. Ø - Phase angle

F. C - Capacitance

G. L - Inductance

H. H - Henry

I. mh - Millihenry

J. Mh - Megahenry

K. f - Frequency

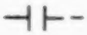
L. F - Farad

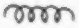
M. μF - Microfarad

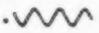
N. $\mu\mu$F - Picofarad

O. R - Resistance

P. - AC source

Q.  - Capacitor

R.  - Inductor

S.  - Resistor

T. P_A - Apparent power

U. P_T - True power

V. P.F. - Power factor

W. H_z - Hertz

X. VAR - Volt-amps reactive

Y. VAC - Volts alternating current

Z. cps - Cycles per second

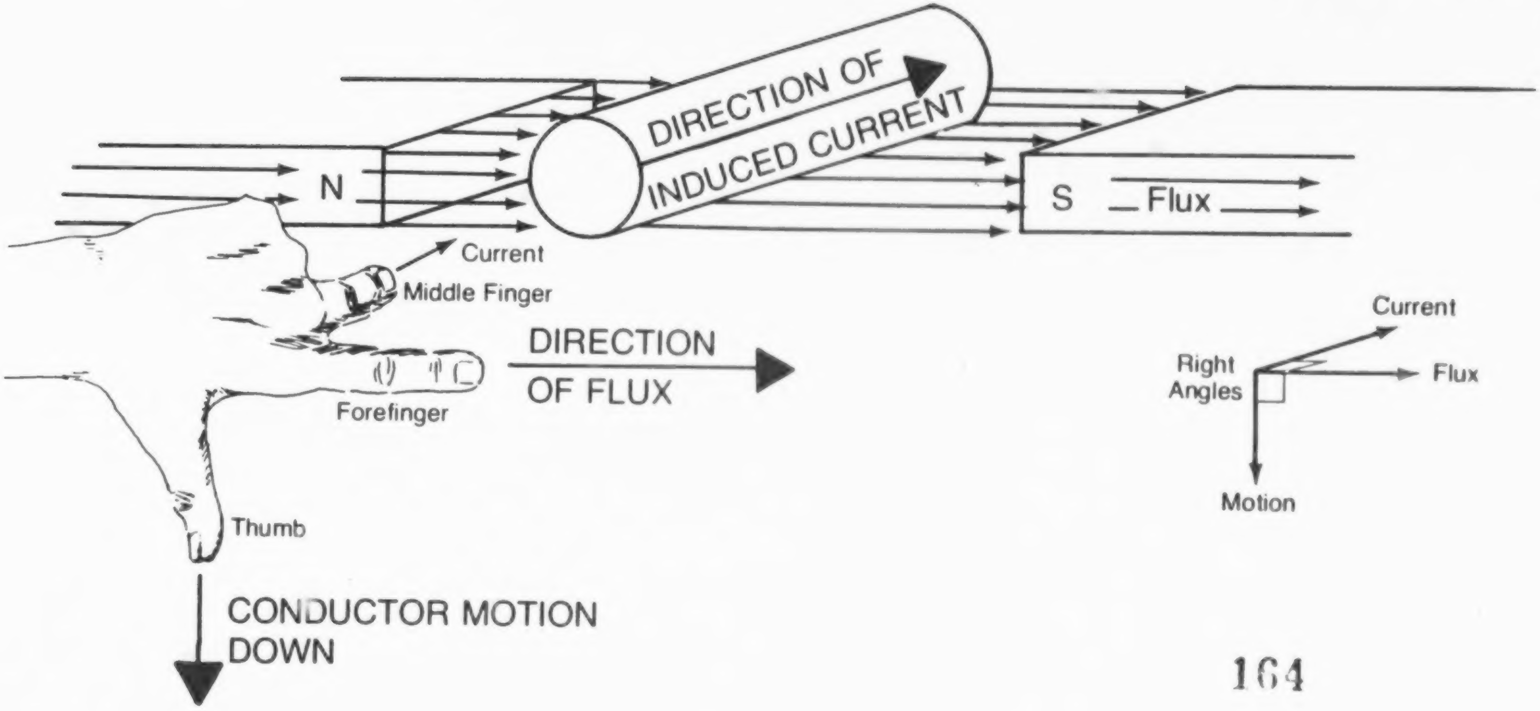
AA. kVar - Kilovolt ampere reactance

BB. kw - Kilowatt

CC. kHz - Kilohertz

DD. MHz - Megahertz

The Left Hand Generator Rule

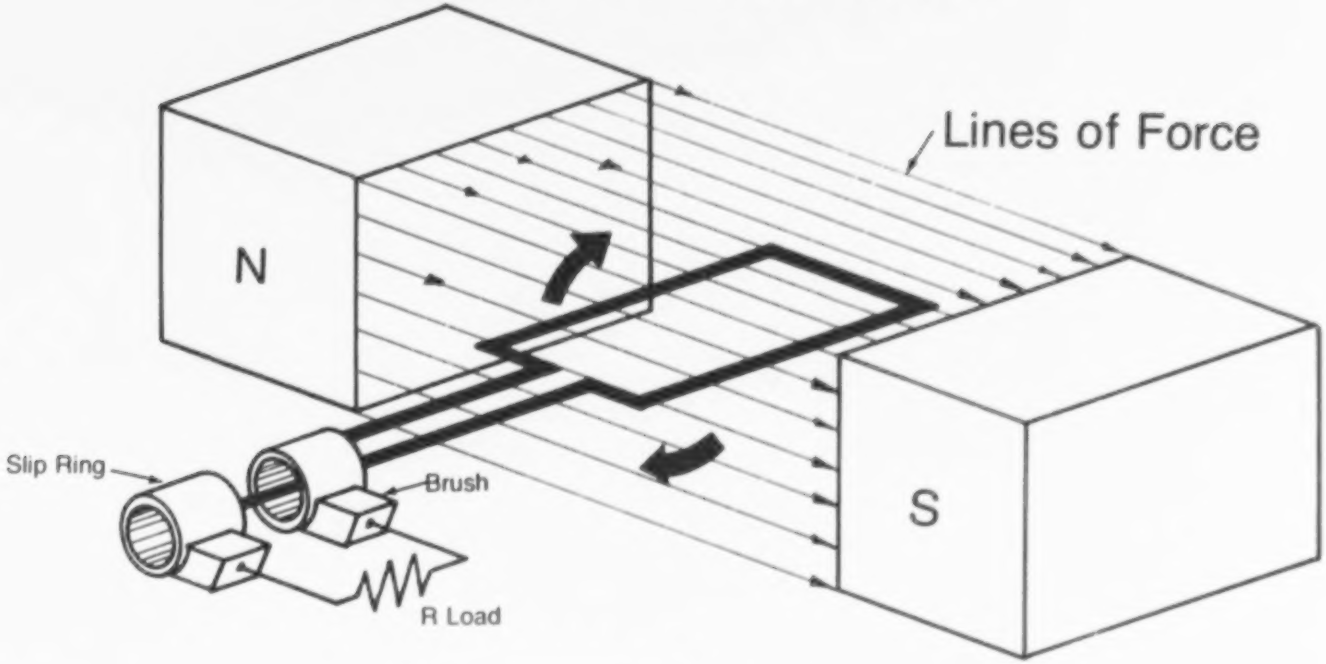

DIRECTION OF
INDUCED CURRENT
N
S
Flux
Current
Middle Finger
DIRECTION
OF FLUX
Forefinger
Thumb
CONDUCTOR MOTION
DOWN

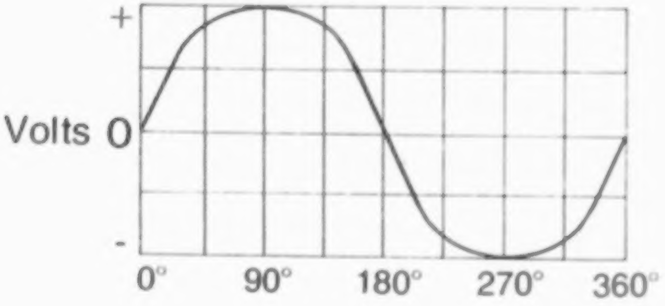
Current
Right
Angles
Flux
Motion

G105B-17

TM #1

Simple AC Generator

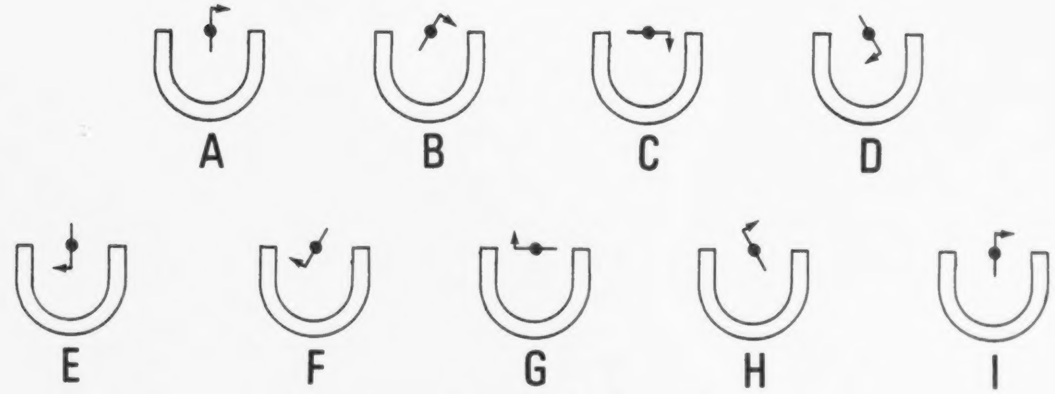

Lines of Force
N
S
Slip Ring
Brush
R Load



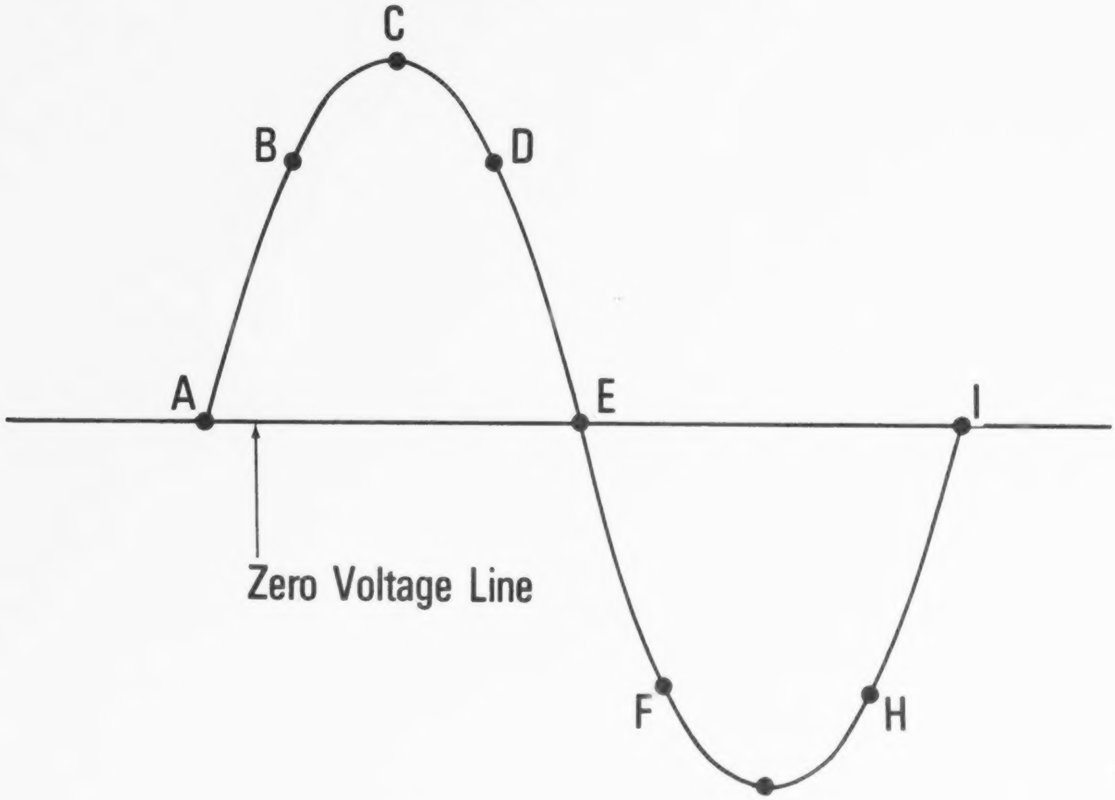
(Loop Shown in Maximum Voltage Position)

AC Generation

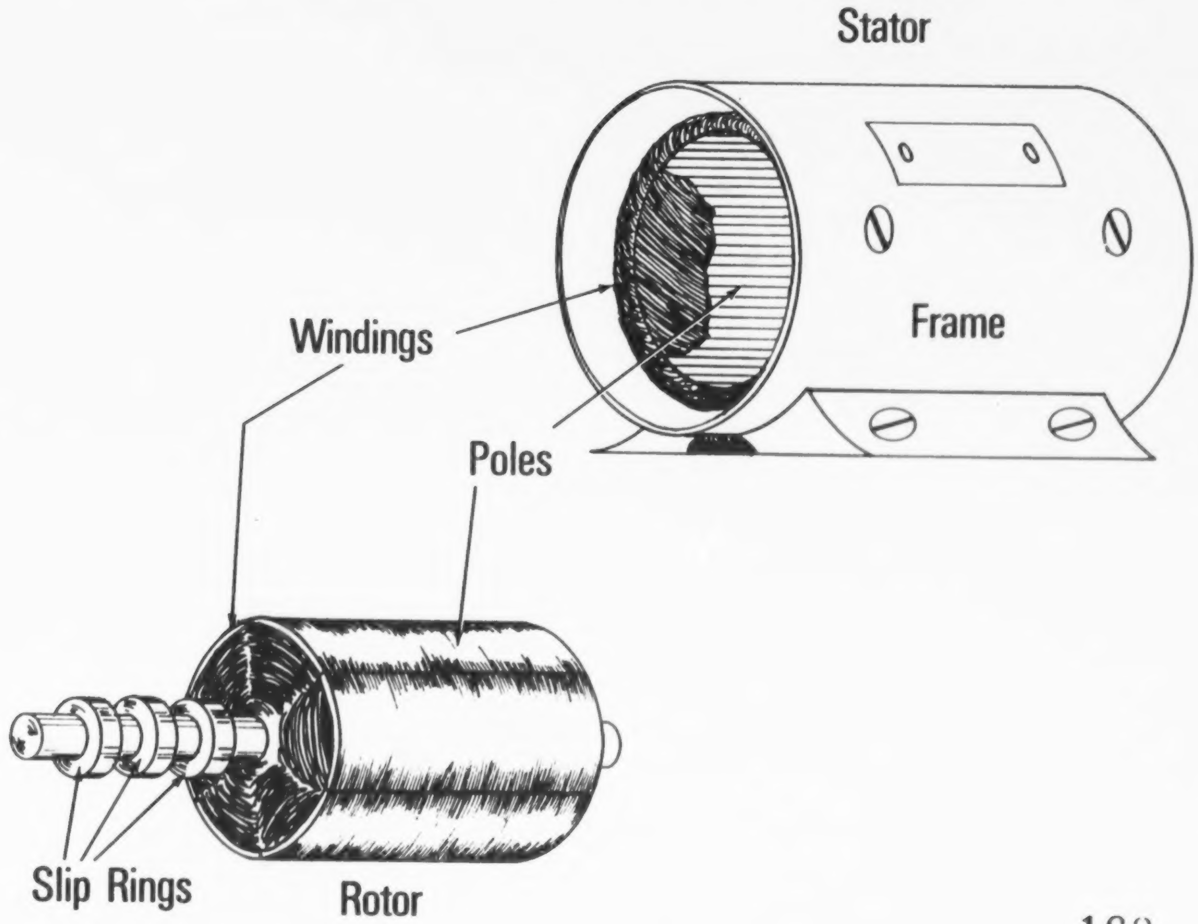
Indicated Rotor Generator Positions



Corresponding Waveform Points


C
B
D
A
E
I
Zero Voltage Line
F
H
G

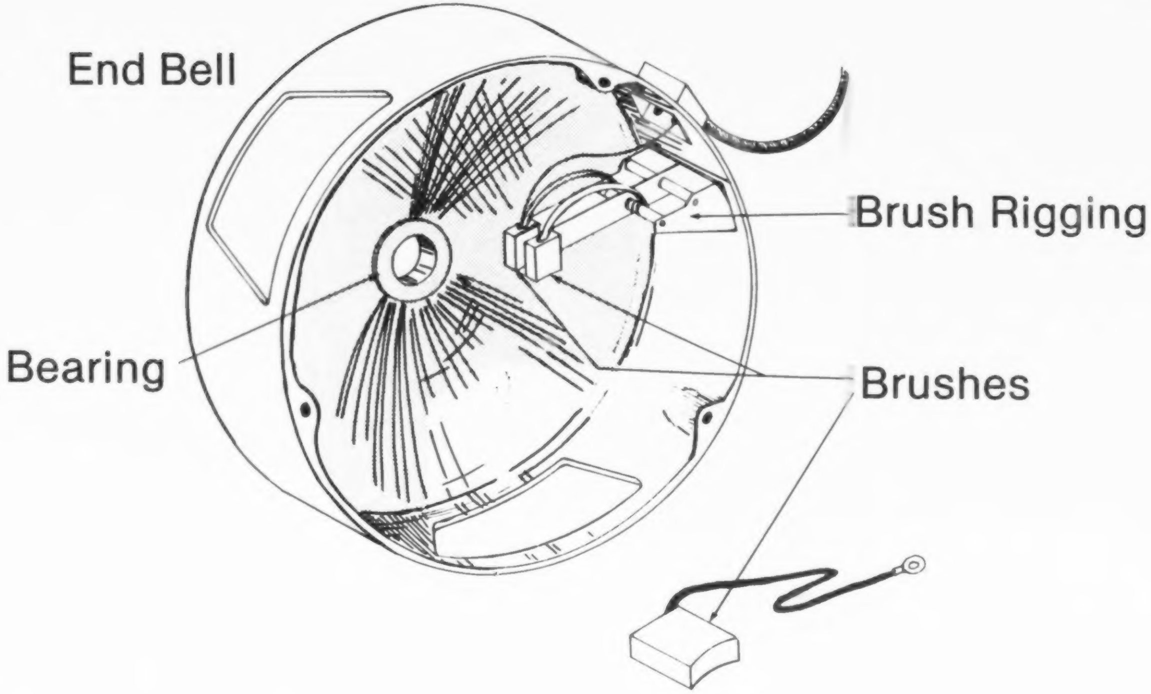
Principal Generator Parts


Stator
Windings
Frame
Poles
Slip Rings
Rotor

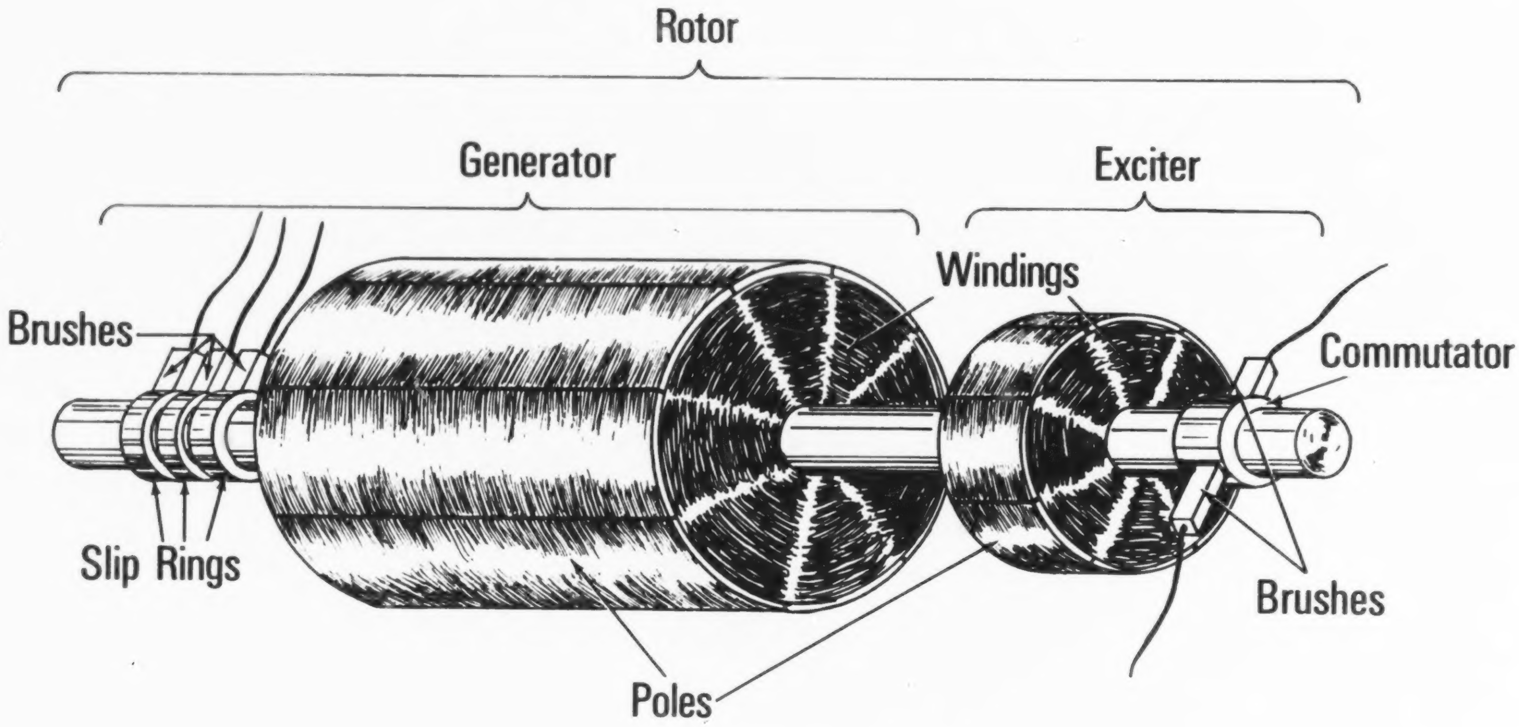
G105B-23

TM #4

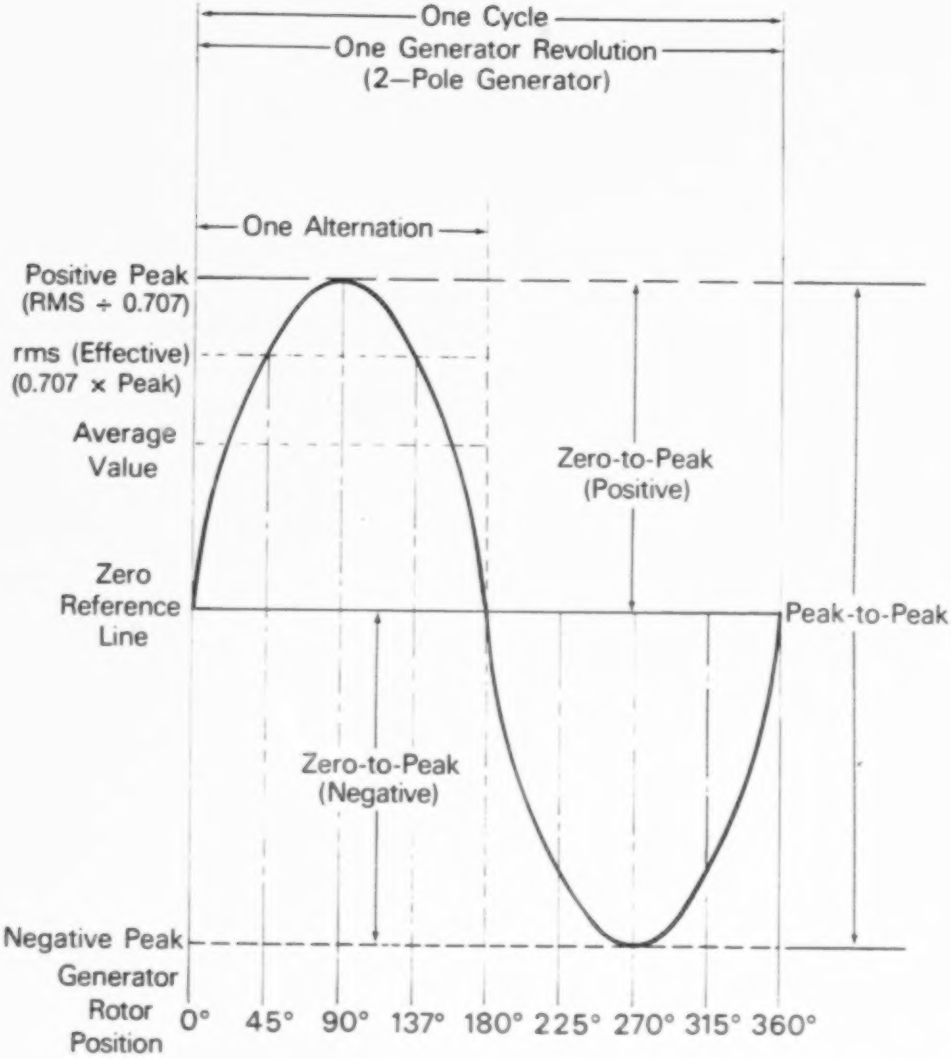
Principal Generator Parts
(Continued)


End Bell
Brush Rigging
Bearing
Brushes

Generator Rotor With Shaft-Driven Exciter


Rotor
Generator
Exciter
Brushes
Windings
Commutator
Slip Rings
Brushes
Poles

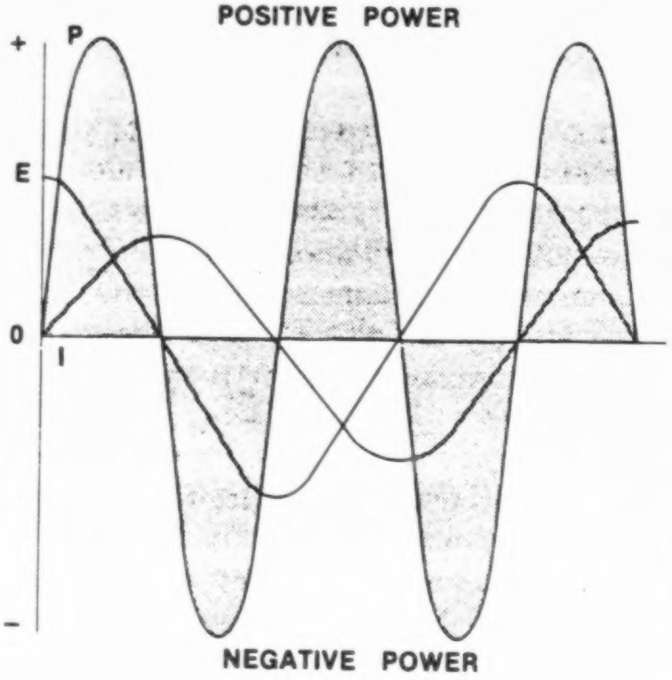
AC Waveform Components


One Cycle
One Generator Revolution
(2—Pole Generator)
One Alternation
Positive Peak
(RMS ÷ 0.707)
rms (Effective)
(0.707 × Peak)
Average
Value
Zero-to-Peak
(Positive)
Zero
Reference
Line
Peak-to-Peak
Zero-to-Peak
(Negative)
Negative Peak
Generator
Rotor
Position
0°
45°
90°
137°
180°
225°
270°
315°
360°

Values of Sine Wave Alternating Current

WHEN E & I ARE ALIKE - POWER IS POSITIVE

WHEN E & I ARE NOT ALIKE - POWER IS NEGATIVE



I LAGS E BY 90°

POWER = E × I × COS θ

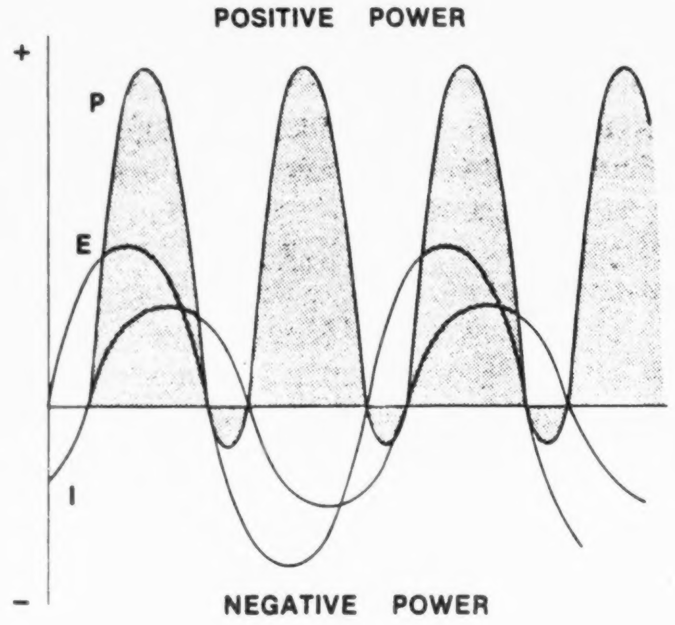
POWER = E × I × 0

POWER = 0

Used with permission of Aviation Maintenance Publishers, Inc., Riverton, Wyoming

Values of Sine Wave Alternating Current

(Continued)



I LAGS E BY 45°

POWER = E × I × COS 45°

POWER = E × I × 0.707

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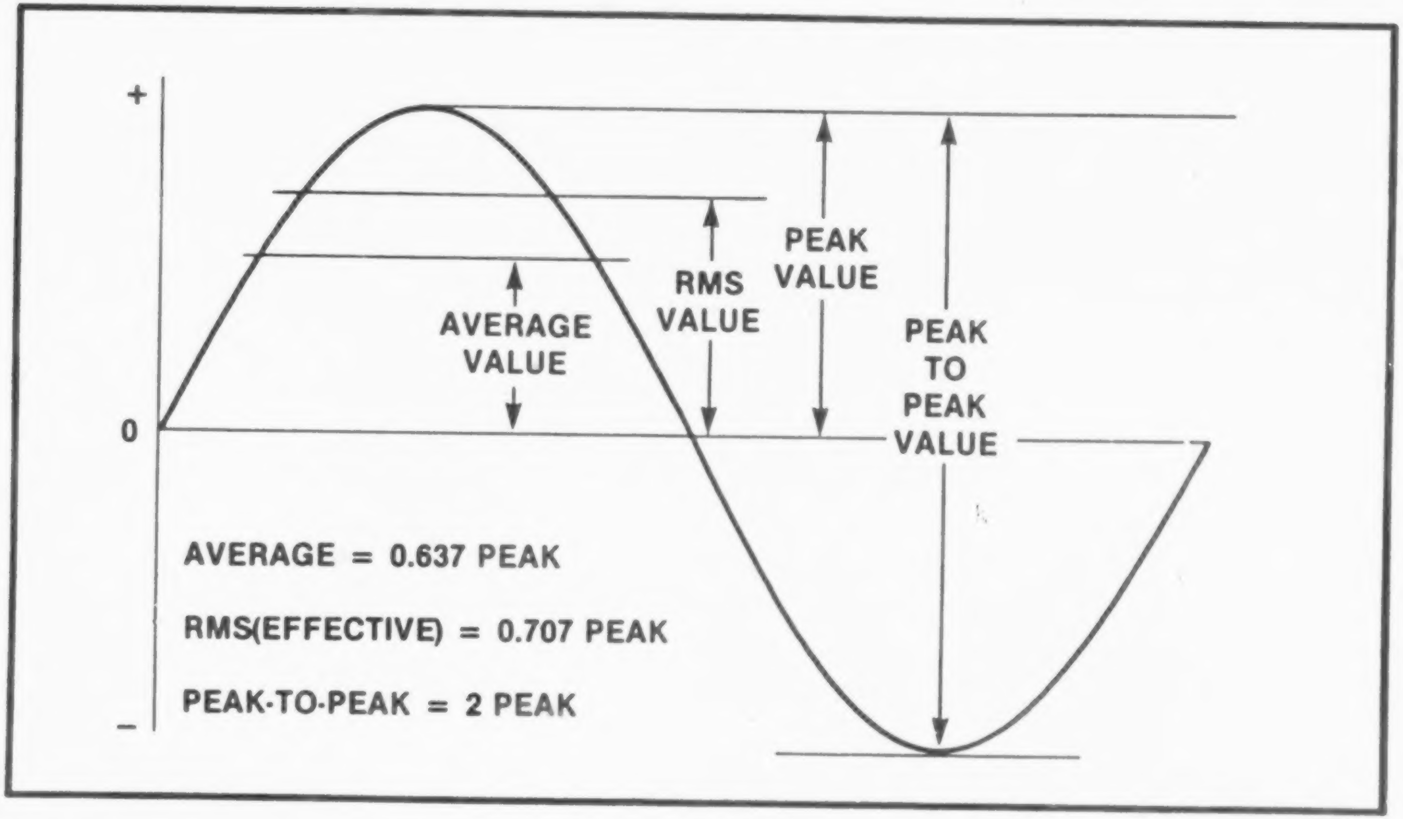
Values of Sine Wave Alternating Current

(Continued)


+
0
−
PEAK VALUE
RMS VALUE
AVERAGE VALUE
PEAK TO PEAK VALUE

AVERAGE = 0.637 PEAK

RMS(EFFECTIVE) = 0.707 PEAK

PEAK-TO-PEAK = 2 PEAK

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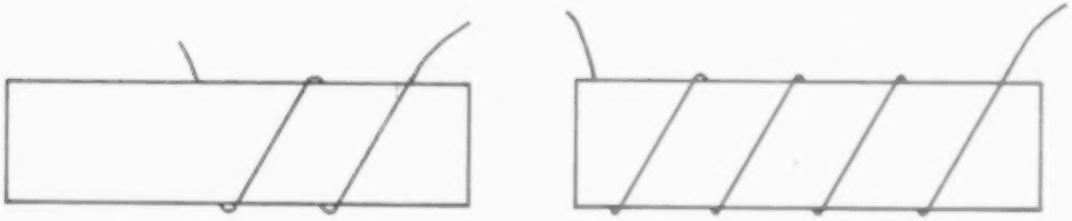
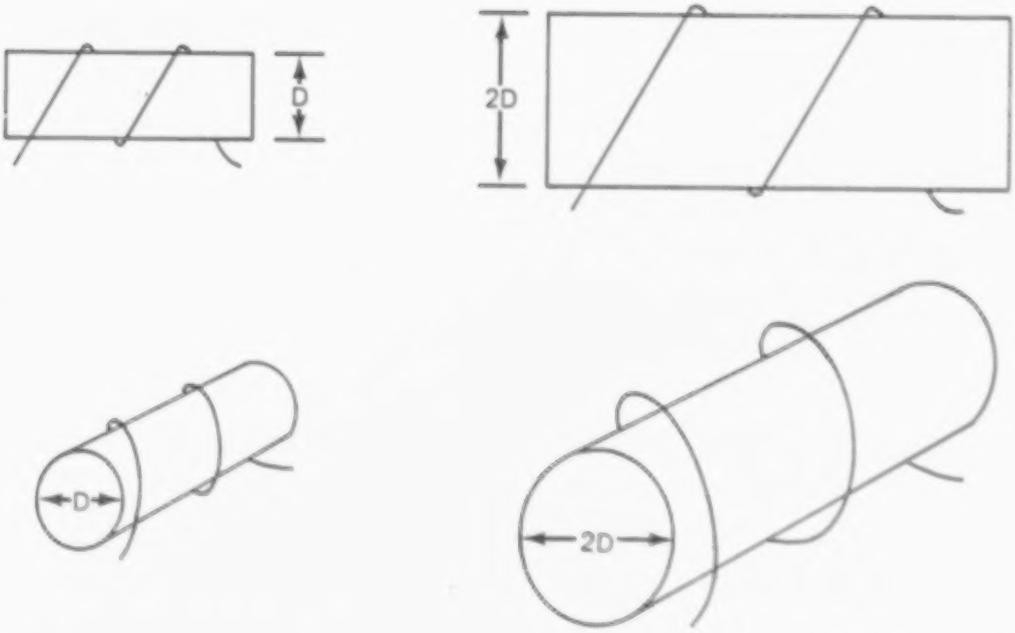
Factors That Determine Inductance



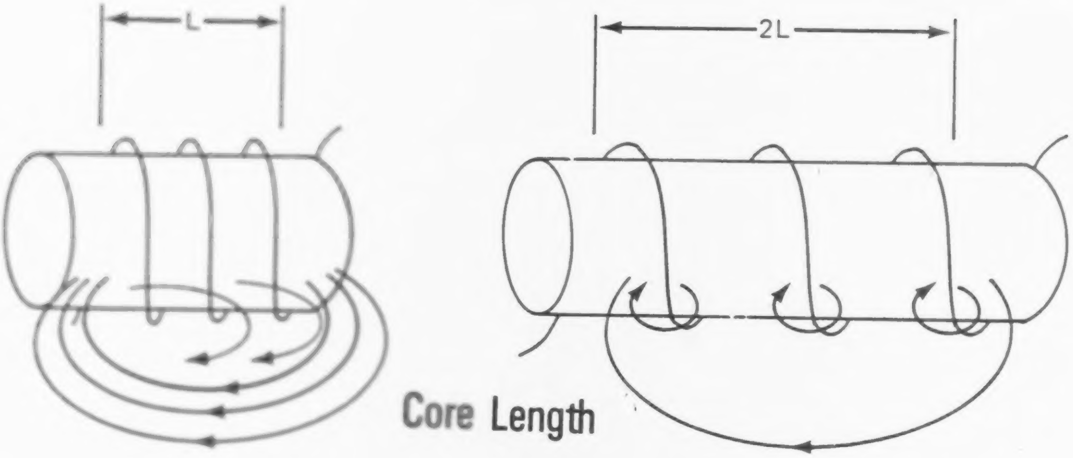
Number of Turns of Coil



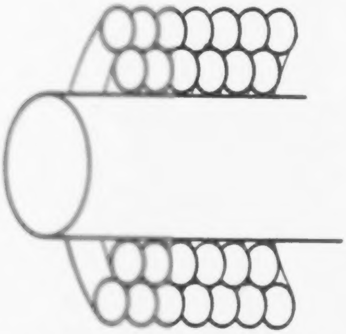
Core Diameter

Factors That Determine Inductance

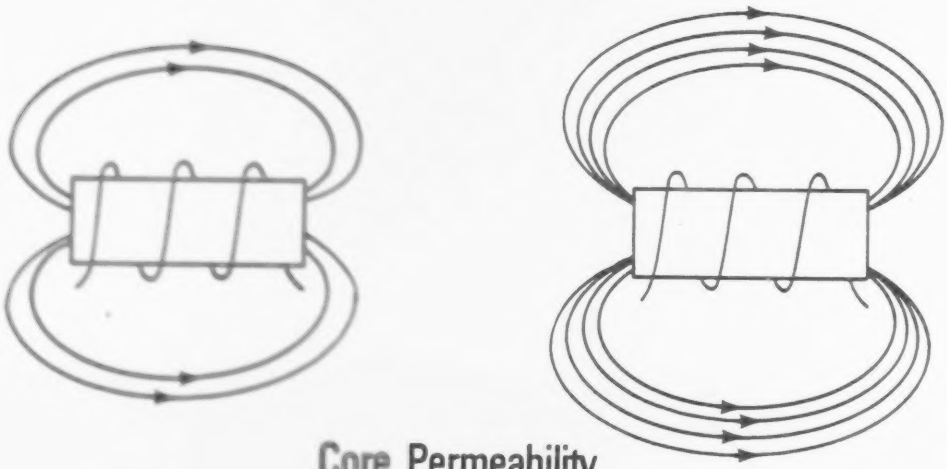
(Continued)



Core Length

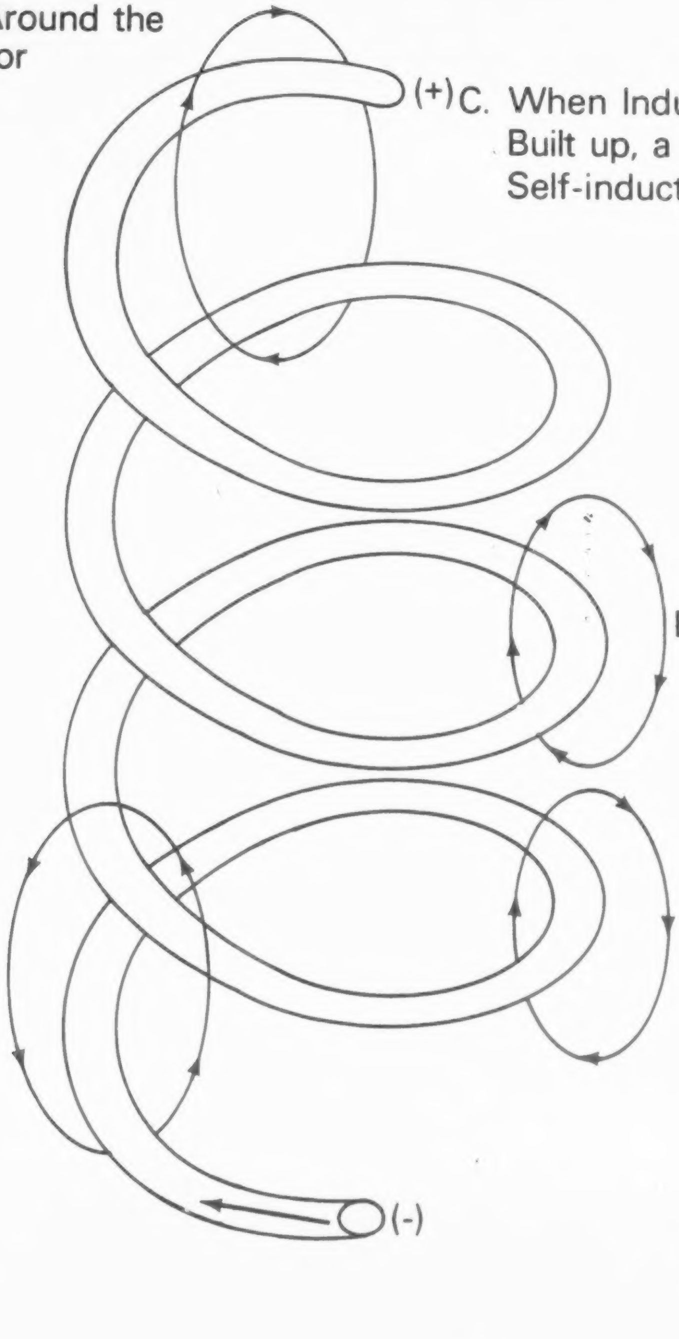


Number of Core Coil Layers



Core Permeability

Inductor Build-up



A. Current Through Conductor Creates a Flux Around the Conductor

C. When Inductor Field is Built up, a Ccemf or Self-inductance Exists

B. Flux Lines Oppose, Causing Cemf

Capacitor Construction

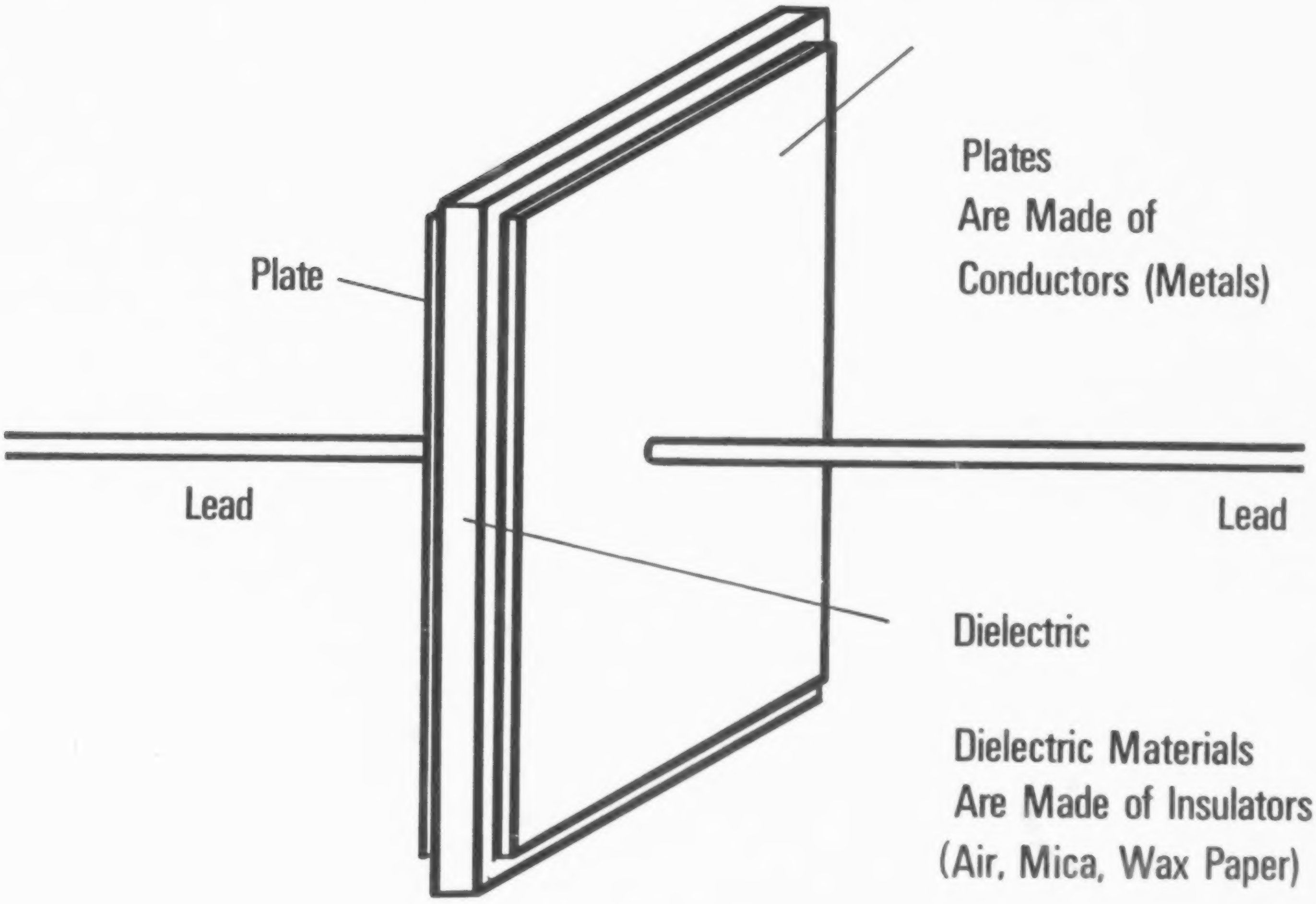
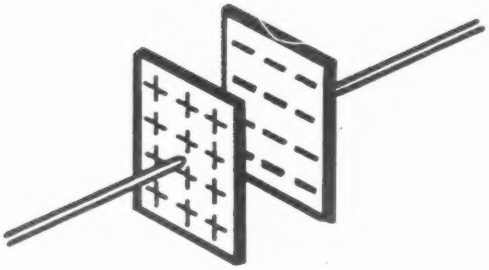


Plate
Lead
Lead
Dielectric

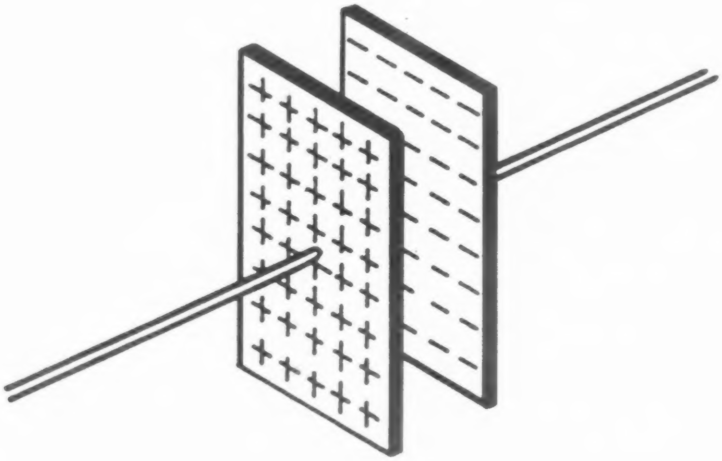
Plates
Are Made of
Conductors (Metals)

Dielectric Materials
Are Made of Insulators
(Air, Mica, Wax Paper)

Plate Area

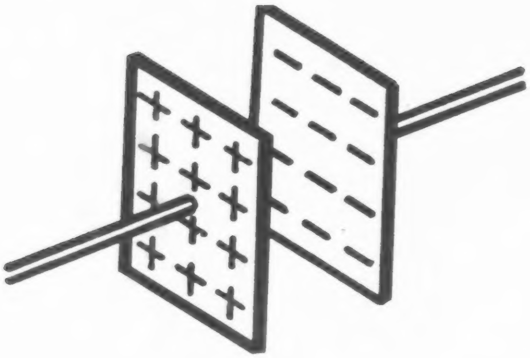


Larger Plates Hold More Electrons

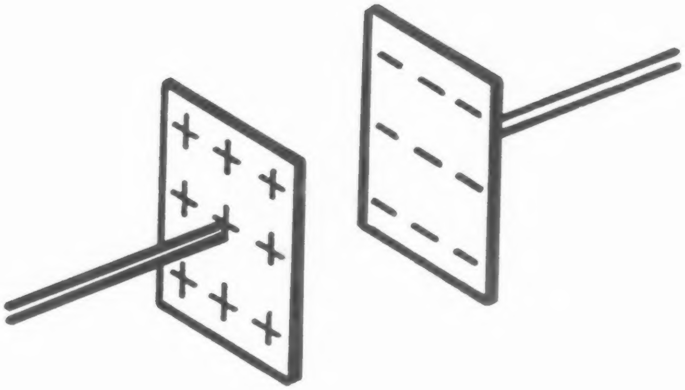


Increased Plate Area Increases Capacitance

Plate Distance

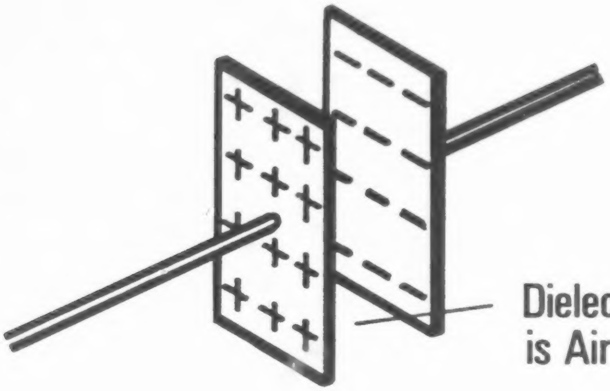


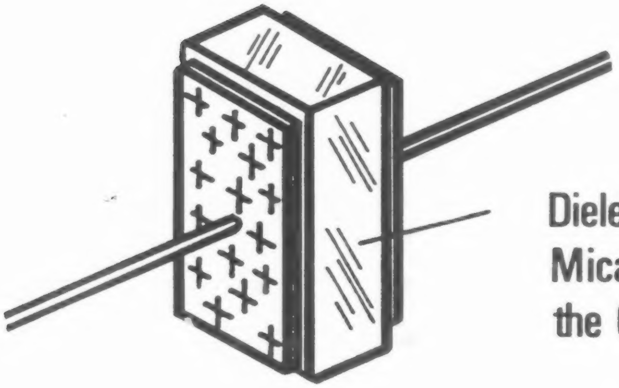
The Distance Between Two Charges Determines Their Effect on One Another



Increasing Distance Between the Plates Decreases Capacitance

Effect of the Dielectric

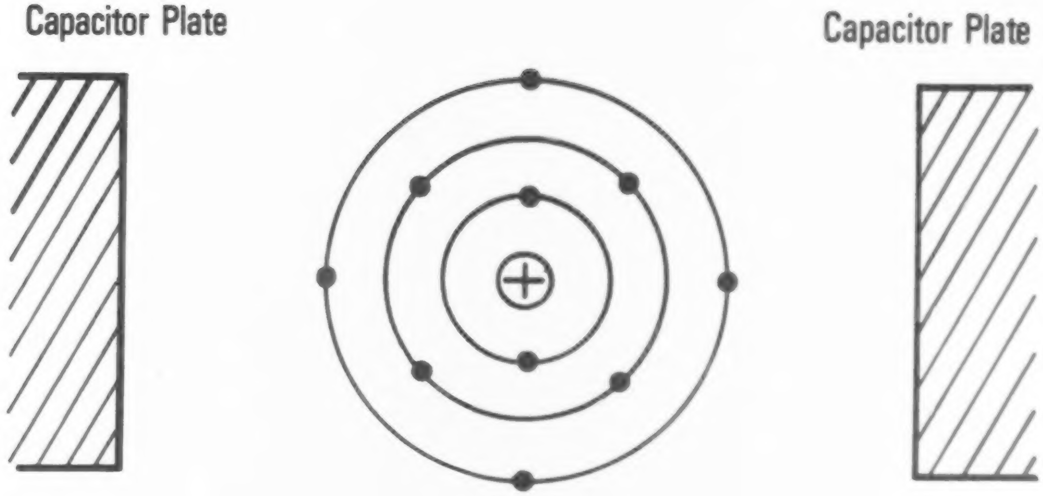

Dielectrical Material
is Air


Dielectrical Material is Mica
Mica Dielectric Increases
the Capacitance

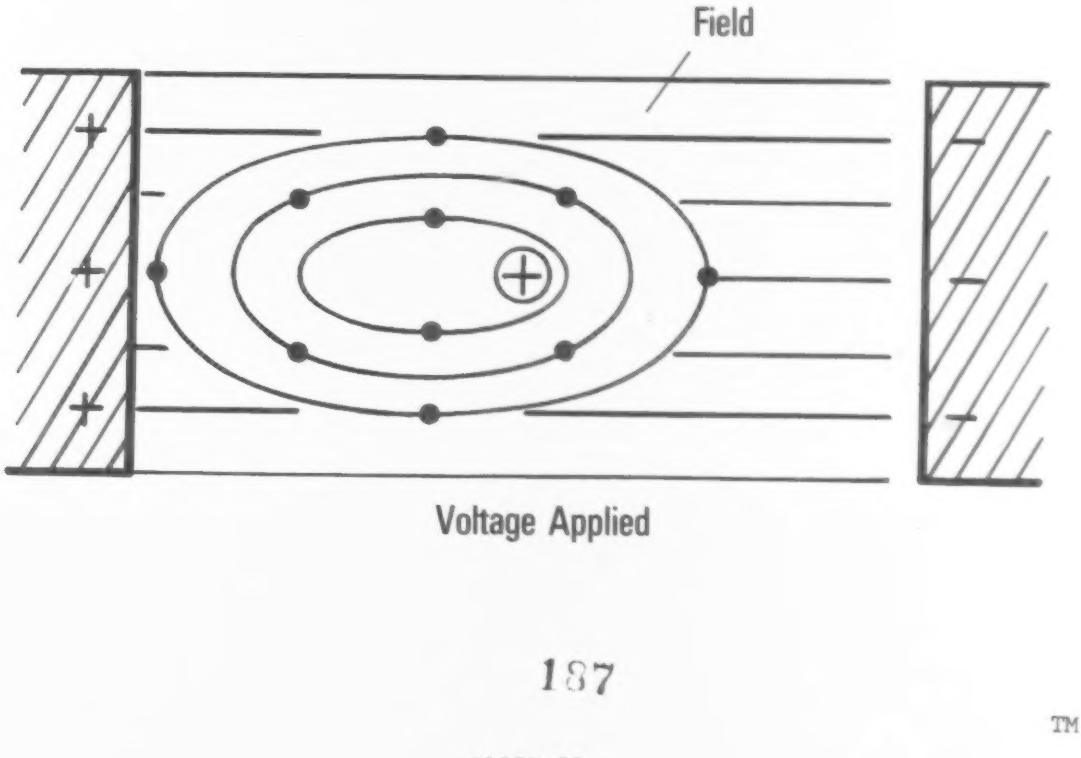
Changing the Dielectric Material Changes the Capacitance

Typical Dielectrics		
Type	Constant	Breakdown
Air	1.0	-----
Mica	5.4	5000 V/Mil
Teflon	2.1	1500 V/Mil
Paper	3.0	200 V/Mil

Electric Field Effect on Capacitors

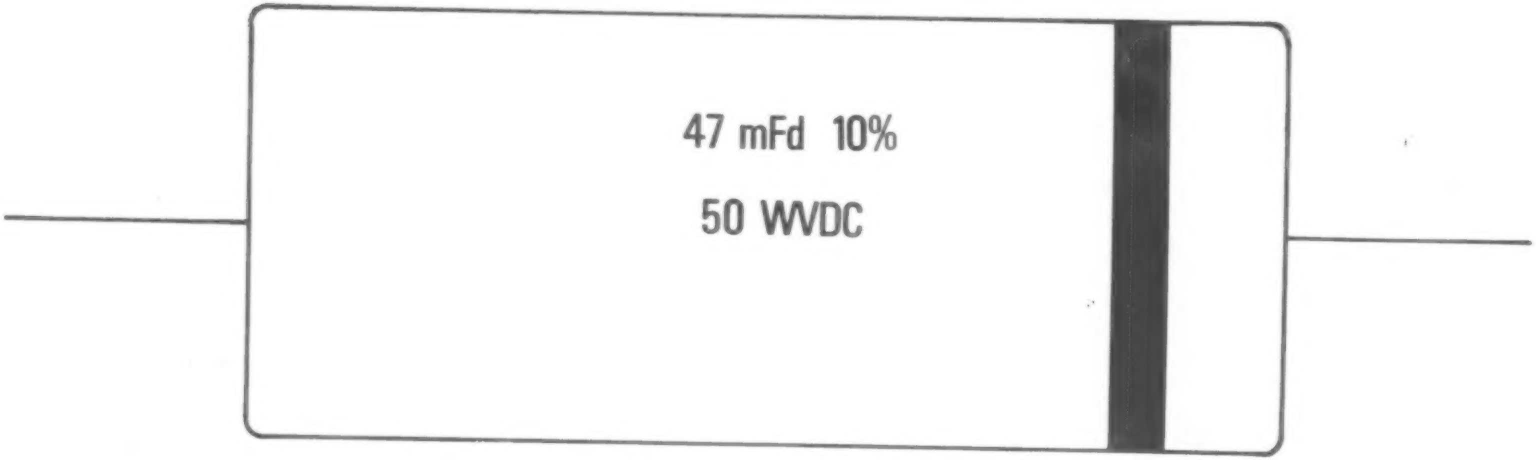

Capacitor Plate
Capacitor Plate
+

No Voltage



Voltage Applied

Capacitor Specifications


47 mFd 10%
50 WVDC

G105B-53

TM #19

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WORKBOOK SUPPLEMENT #1 - Convert from One Voltage Measurement to Another and Label Waveform Components

It is important to distinguish between the various types of AC Voltage measurements and to convert from one to another. Use your knowledge of these fundamentals to answer the following questions. Write the correct answers in the blanks.

A. A sine wave measures 60 volts peak-to-peak. What is the peak voltage?

____

B. If the above voltage is to be measured with a multimeter, what voltage will the meter read and what type voltage is it? ______________________________

______________ ______________________________

C. A diagram specifies that a voltage is supposed to be 400 volts.

(1) What type voltage is this? ______________________________

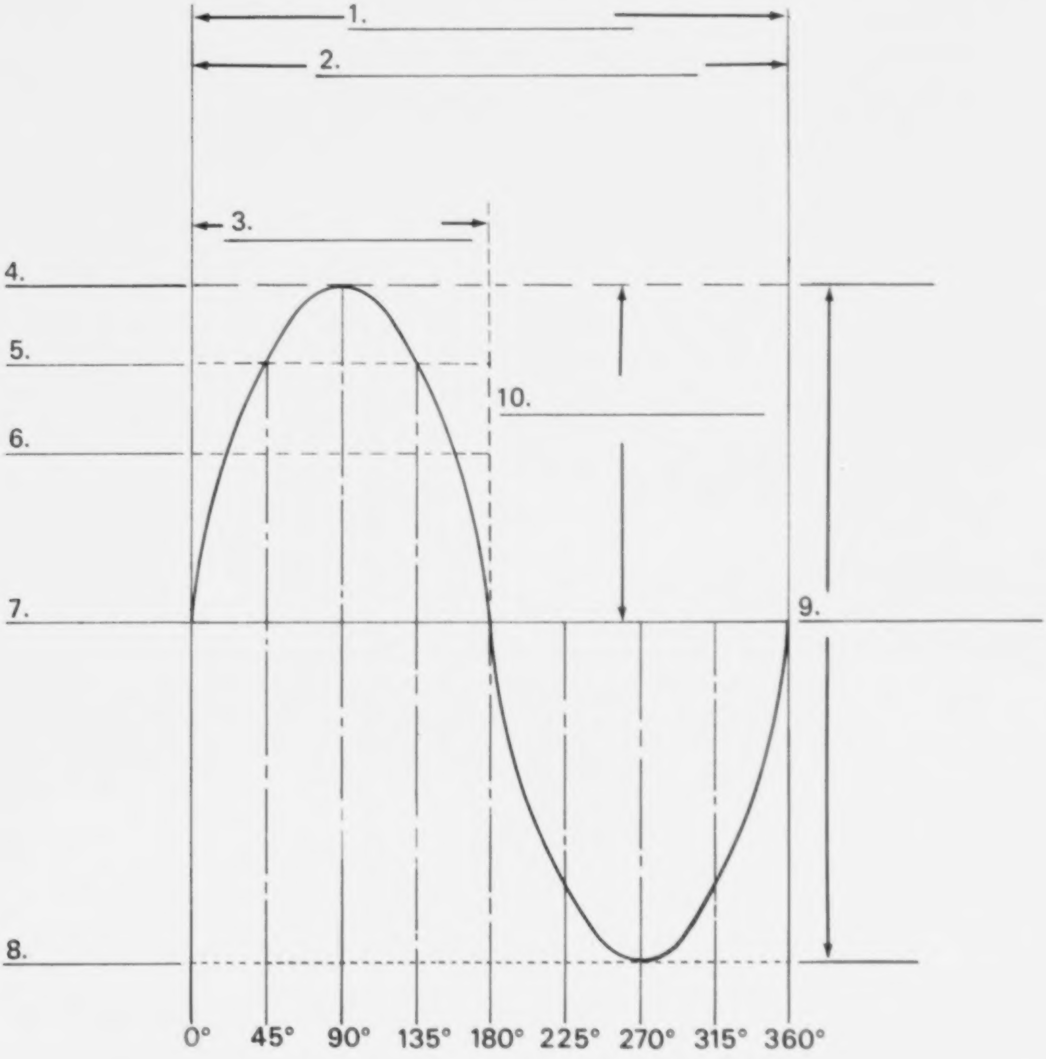
(2) What is the root mean square voltage? ______________________________

(3) What is the equivalent DC voltage? ______________________________

D. In order to measure a 170-volt root-mean-square signal on an oscilloscope, you will measure a peak-to-peak voltage of ______________________________

____

E. Label the AC waveform components in the drawing below. Write the correct names in the blanks.


1.
2.
3.
4.
5.
6.
7.
8.
9.
10.
0°
45°
90°
135°
180°
225°
270°
315°
360°

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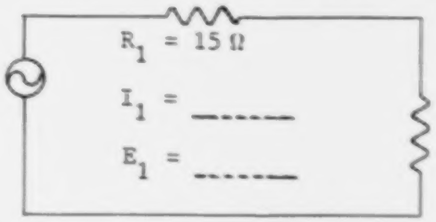
WORKBOOK SUPPLEMENT #2 - Determine Current, Resistance, Voltage, and Power in Resistive AC Circuits

Apply Ohm's Law for AC circuits to answer the following questions. Show your work and record the correct values in the blanks provided.

A. E_T = 120 VAC

I_T = ______

R_T = ______



R_1 = 15 Ω

I_1 = ______

E_1 = ______

R_2 = 5 Ω

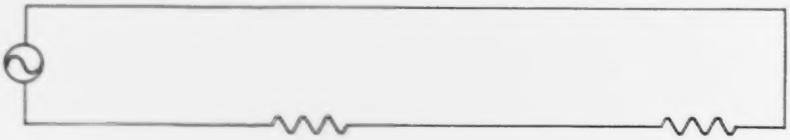
I_2 = ______

E_2 = ______

B. E_T = 100 VAC

I_T = ______

R_T = ______



E_1 = 60 V

R_1 = ______

I_1 = ______

E_2 = ______

R_2 = ______

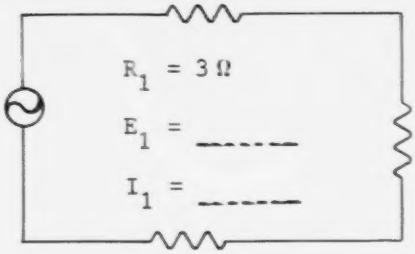
I_2 = 4 A

C. E_T = 110 VAC

60 Hz

I_T = ______

R_T = ______



R_1 = 3 Ω

E_1 = ______

I_1 = ______

R_2 = 4 Ω

E_2 = ______

I_2 = ______

R_3 = 4 Ω

E_3 = ______

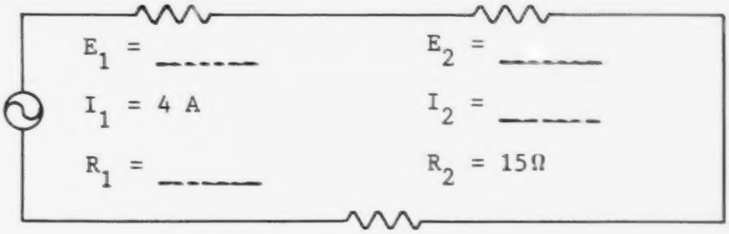
I_3 = ______

D. E_T = 200 VAC

400 Hz

I_T = ______

R_T - ______



E_1 = ______

I_1 = 4 A

R_1 = ______

E_2 = ______

I_2 = ______

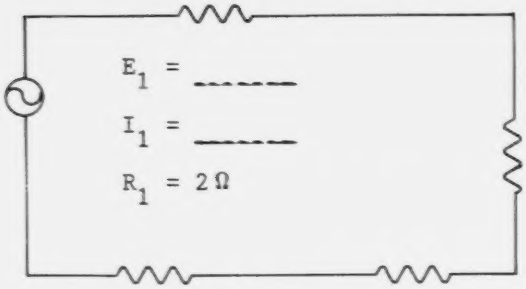
R_2 = 15 Ω

E_3 = ______

I_3 = ______

R_3 = 20 Ω

WORKBOOK SUPPLEMENT #2



E. E_T = 220 VAC

I_T = ______

R_T = ______

E_1 = ______

I_1 = ______

R_1 = 2 Ω

E_2 = ______

I_2 = ______

R_2 = 4 Ω

E_4 = ______

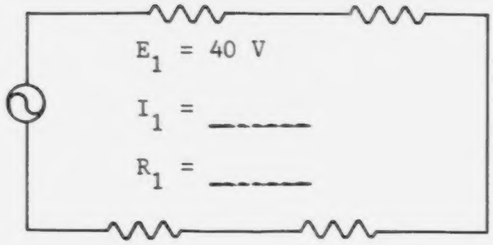
I_4 = ______

R_4 = 8 Ω

E_3 = ______

I_3 = ______

R_3 = 6 Ω



F. E_T = 440 VAC

I_T = ______

R_T = ______

E_1 = 40 V

I_1 = ______

R_1 = ______

E_2 = 80 V

I_2 = ______

R_2 = ______

E_4 = ______

I_4 = 4 A

R_4 = ______

E_3 = ______

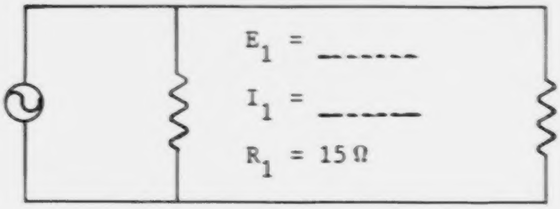
I_3 = ______

R_3 = 30 Ω

G. E_T = 150 VAC

I_T = ______

R_T = ______



E_1 = ______

I_1 = ______

R_1 = 15 Ω

E_2 = ______

I_2 = ______

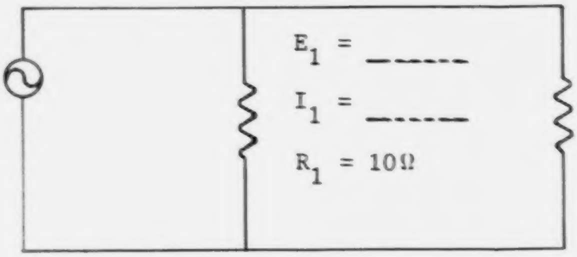
R_2 = 30 Ω

H. E_T = 100 VAC

400 Hz

I_T = ______

R_T = 5 Ω



E_1 = ______

I_1 = ______

R_1 = 10 Ω

E_2 = ______

I_2 = ______

R_2 = ______

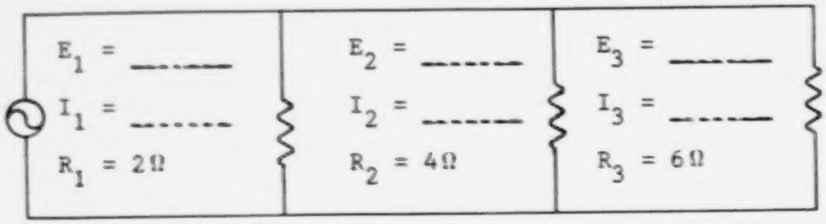
WORKBOOK SUPPLEMENT #2

I. E_T = 120 VAC

1kHZ

I_T = ______

R_T = ______



E_1 = ______

I_1 = ______

R_1 = 2Ω

E_2 = ______

I_2 = ______

R_2 = 4Ω

E_3 = ______

I_3 = ______

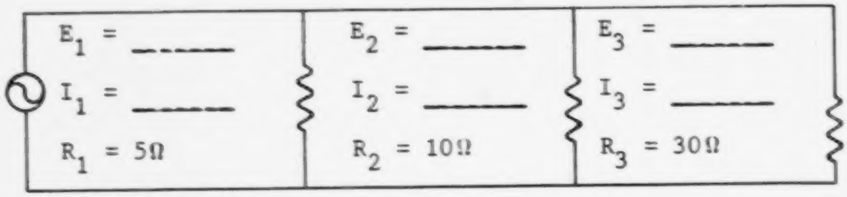
R_3 = 6Ω

J. E_T = 120 VAC

60 Hz

I_T = 40 A

R_T = ______



E_1 = ______

I_1 = ______

R_1 = 5Ω

E_2 = ______

I_2 = ______

R_2 = 10Ω

E_3 = ______

I_3 = ______

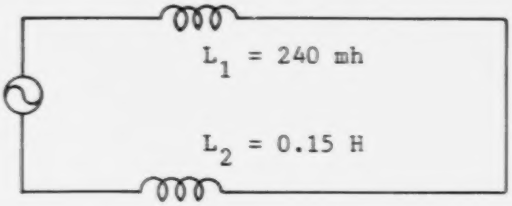
R_3 = 30Ω

WORKBOOK SUPPLEMENT #3 - Determine Values in R-L Circuits

Apply the appropriate formulas to answer the following questions. Show all work and record the correct values in the blanks provided.

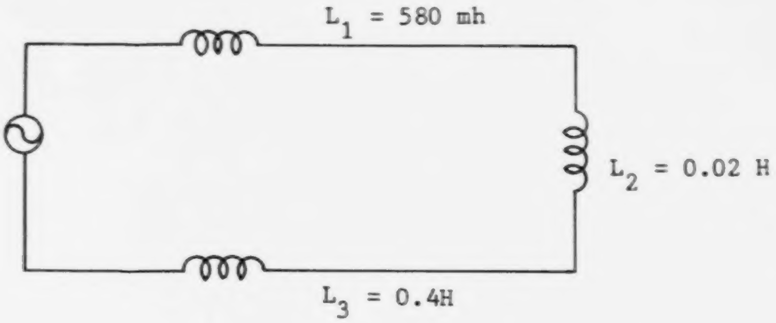
A. 120 VAC

60 cps



L_T = ______

X_L = ______



B. 120 VAC

400 cps

L_2 = 0.02 H

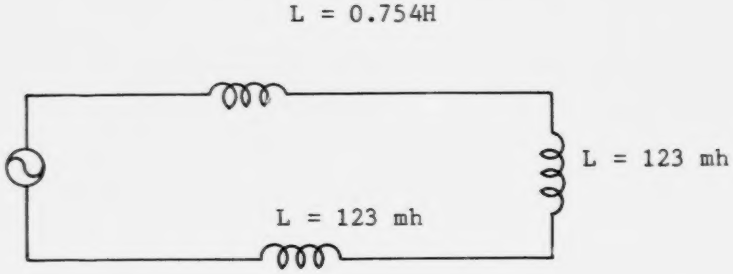
L_T = ______

L_3 = 0.4 H

X_L = ______

C. 120 VAC

60 Hz

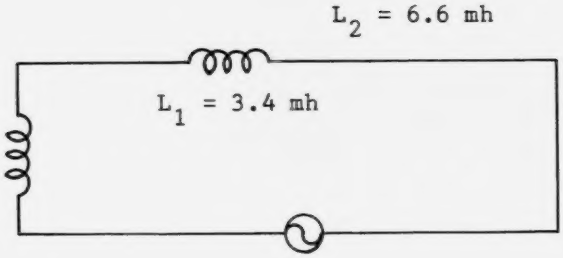

L = 0.754H
L = 123 mh
L = 123 mh

L_T = ______

X_L = ______

D. 220 VAC

600 Hz

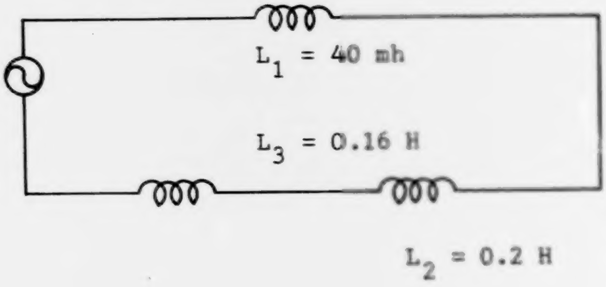

L_2 = 6.6 mh
L_1 = 3.4 mh

L_T = ______

X_L = ______

E. 120 VAC

60 cps

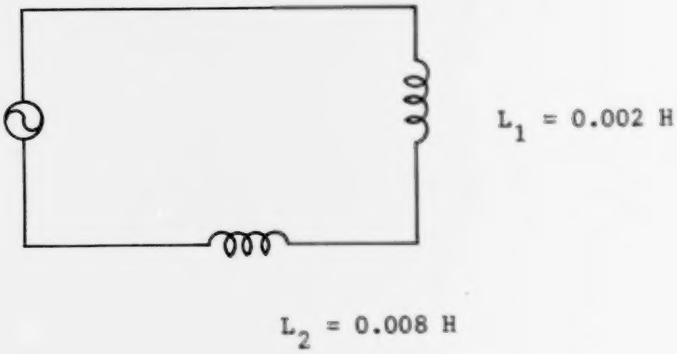

L_1 = 40 mh
L_3 = 0.16 H
L_2 = 0.2 H

L_T = ______

X_L = ______

F. 120 VAC

400 Hz

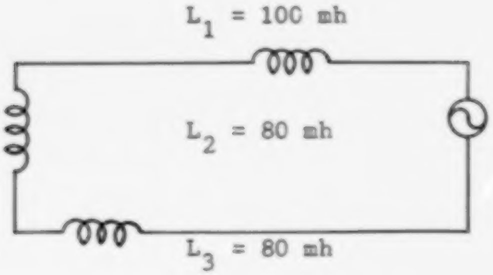

L_1 = 0.002 H
L_2 = 0.008 H

L_T = ______

X_L = ______

G. 120 VAC

400 Hz

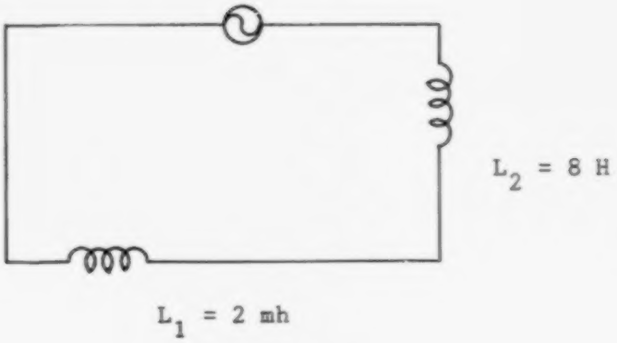

L_1 = 100 mh
L_2 = 80 mh
L_3 = 80 mh

L_T = ______

X_L = ______

H. 200 VAC

400 cps



L_T = ______

X_L = ______

WORKBOOK SUPPLEMENT #3

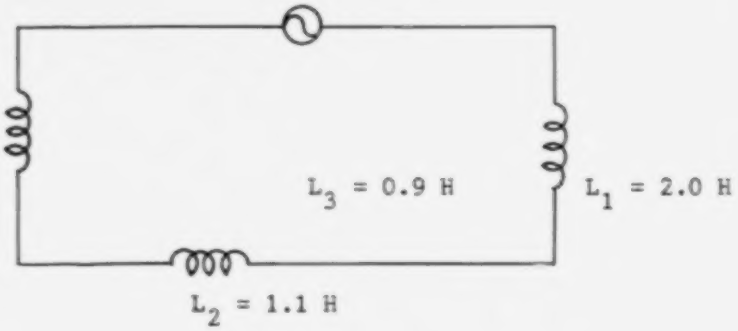
I. E_T = 120 VAC

f = 60 Hz

L_T = ______

X_L = ______

I_T = ______


L_3 = 0.9 H
L_1 = 2.0 H
L_2 = 1.1 H

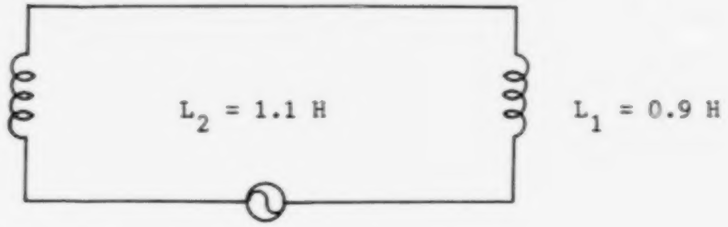
J. E_T = 120 VAC

f = 60 Hz

L_T = ______

X_L = ______

I_T = ______


L_2 = 1.1 H
L_1 = 0.9 H

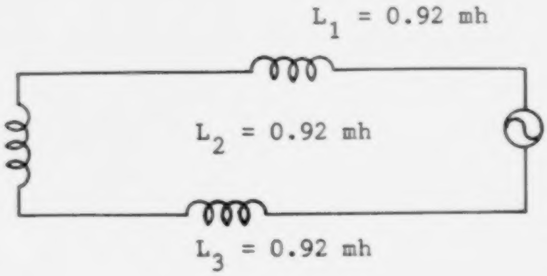
K. E_T = 20 VAC

f = 1 kHz

L_T = ______

X_L = ______

I_T = ______


L_1 = 0.92 mh
L_2 = 0.92 mh
L_3 = 0.92 mh

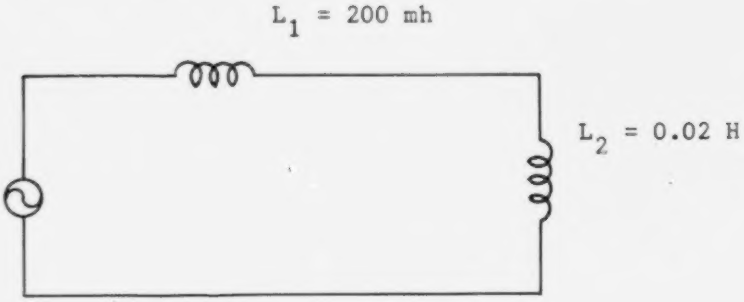
L. E_T = 440 VAC

f = 1 kHz

L_T = ______

X_L = ______

I_T = ______


L_1 = 200 mh
L_2 = 0.02 H

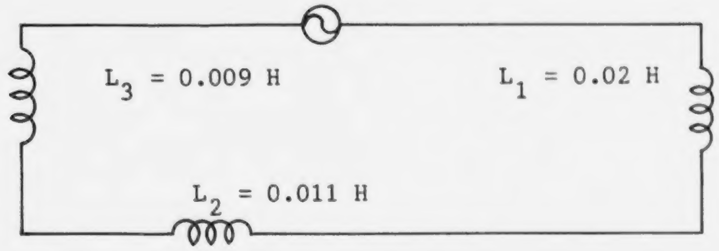
M. E_T = 100 VAC

f = 400 Hz

L_T = ______

X_L = ______

I_T = ______


L_3 = 0.009 H
L_1 = 0.02 H
L_2 = 0.011 H

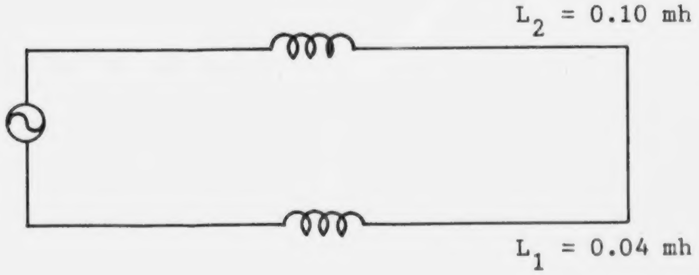
N. E_T = 880 VAC

f = 1 MHz

L_T = ______

X_L = ______

I_T = ______


L_2 = 0.10 mh
L_1 = 0.04 mh

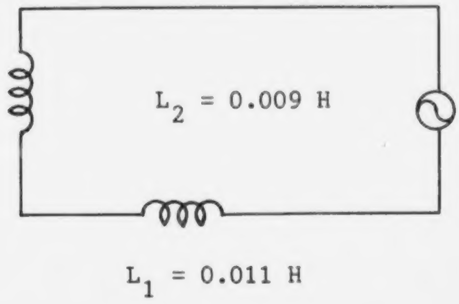
O. E_T = 120 VAC

f = 60 Hz

L_T = ______

X_L = ______

I_T = ______


L_2 = 0.009 H
L_1 = 0.011 H

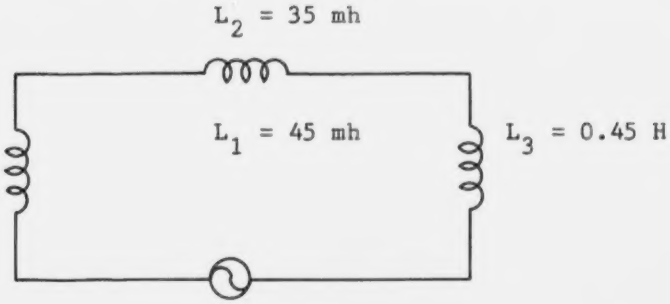
P. E_T = 120 VAC

f = 60 cps

L_T = ______

X_L = ______

I_T = ______


L_2 = 35 mh
L_1 = 45 mh
L_3 = 0.45 H

WORKBOOK SUPPLEMENT #3

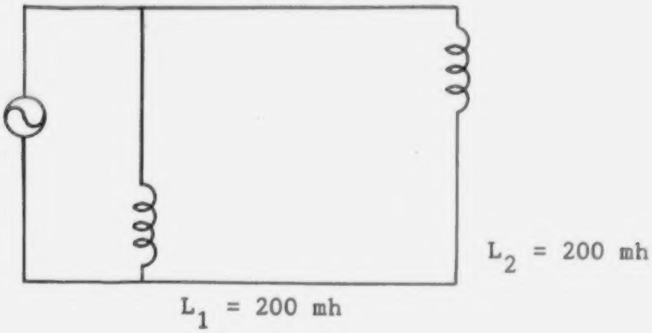
Q. E_T = 120 VAC

f = 60 cps

L_T = ______

X_L = ______

I_T = ______


L_2 = 200 mh
L_1 = 200 mh

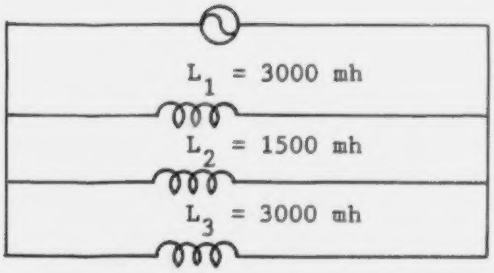
R. E_T = 440 VAC

f = 60 Hz

L_T = ______

X_L = ______

I_T = ______


L_1 = 3000 mh
L_2 = 1500 mh
L_3 = 3000 mh

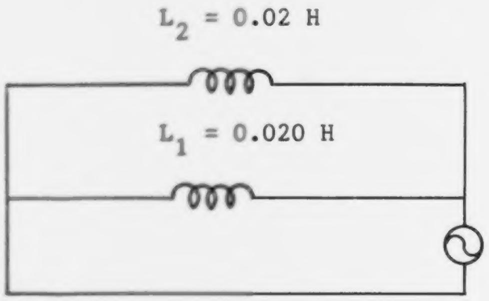
S. E_T = 100 VAC

f = 400 cps

L_T = ______

X_L = ______

I_T = ______


L_2 = 0.02 H
L_1 = 0.020 H

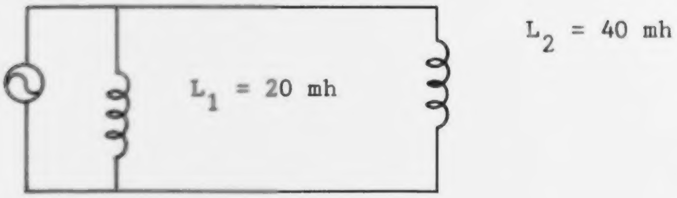
T. E_T = 100 VAC

f = 300 Hz

L_T = ______

X_L = ______

I_T = ______


L_1 = 20 mh
L_2 = 40 mh

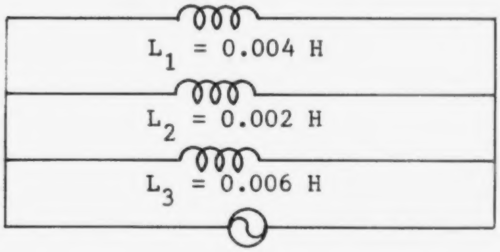
U. E_T = 120 VAC

f = 24 kHz

L_T = ______

X_L = ______

I_T = ______


L_1 = 0.004 H
L_2 = 0.002 H
L_3 = 0.006 H

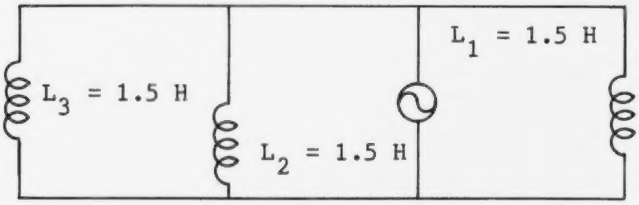
V. E_T = 220 VAC

f = 800 Hz

L_T = ______

X_L = ______

I_T = ______


L_3 = 1.5 H
L_2 = 1.5 H
L_1 = 1.5 H

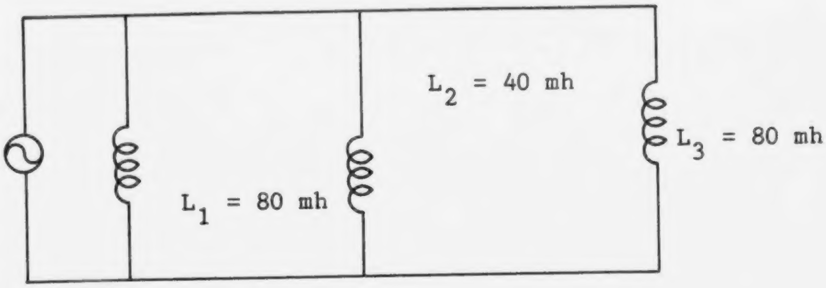
W. E_T = 150 VAC

f = 0.04 kHz

L_T = ______

X_L = ______

I_T = ______


L_1 = 80 mh
L_2 = 40 mh
L_3 = 80 mh

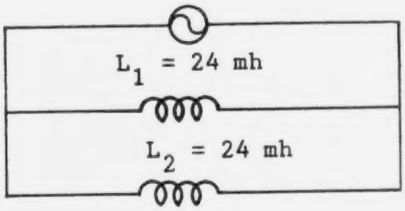
X. E_T = 180 VAC

f = 1.2 kHz

L_T = ______

X_L = ______

I_T = ______


L_1 = 24 mh
L_2 = 24 mh

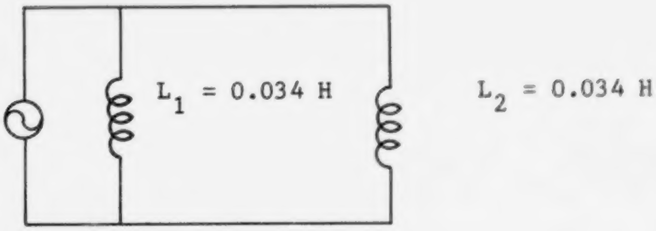
Y. E_T = 440 VAC

f = 400 Hz

L_T = ______

X_L = ______

I_T = ______


L_1 = 0.034 H
L_2 = 0.034 H

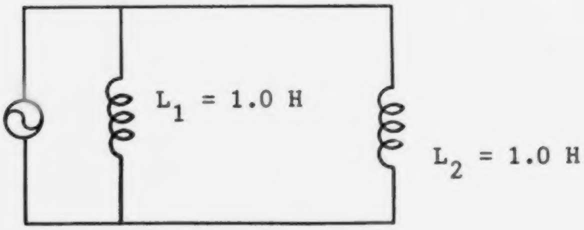
Z. E_T = 220 VAC

f = 400 Hz

L_T = ______

X_L = ______

I_T = ______


L_1 = 1.0 H
L_2 = 1.0 H

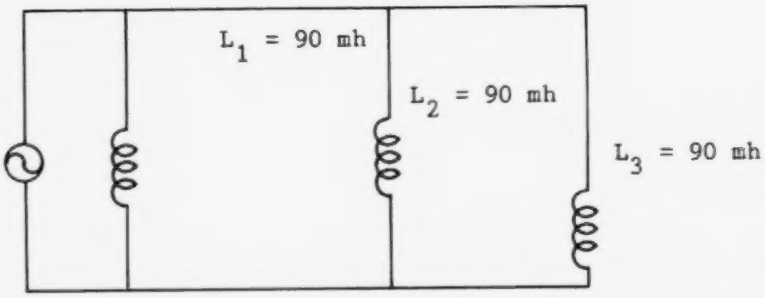
AA. E_T = 200 VAC

f = 1 kHz

L_T = ______

X_L = ______

I_T = ______



L_1 = 90 mh
L_2 = 90 mh
L_3 = 90 mh

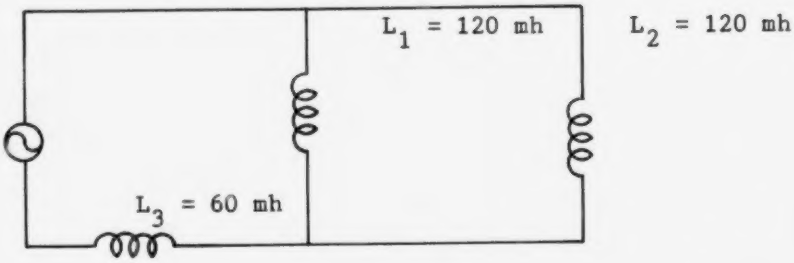
BB. E_T = 120 VAC

f = 400 Hz

L_T = ______

X_L = ______

I_T = ______



L_1 = 120 mh
L_2 = 120 mh
L_3 = 60 mh

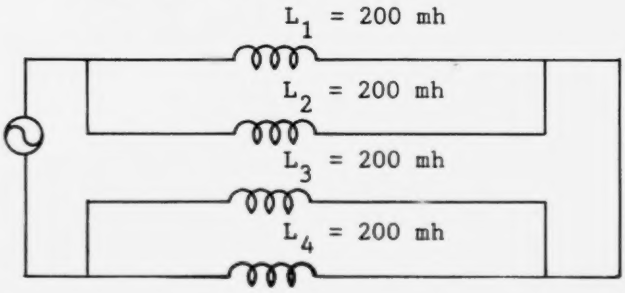
CC. E_T = 200 VAC

f = 0.8 kHz

L_T = ______

X_L = ______

I_T = ______



L_1 = 200 mh
L_2 = 200 mh
L_3 = 200 mh
L_4 = 200 mh

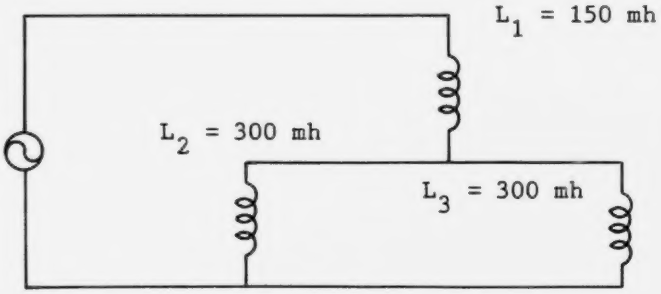
DD. E_T = 150 VAC

f = 400 Hz

L_T = ______

X_L = ______

I_T = ______



L_1 = 150 mh
L_2 = 300 mh
L_3 = 300 mh

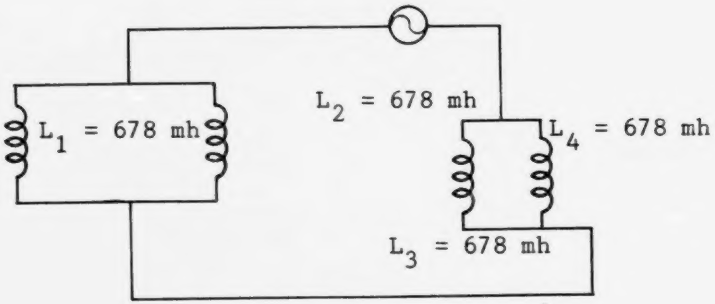
EE. E_T = 500 VAC

f = 60 Hz

L_T = _____

X_L = _____

I_T = _____



L_1 = 678 mh
L_2 = 678 mh
L_4 = 678 mh
L_3 = 678 mh

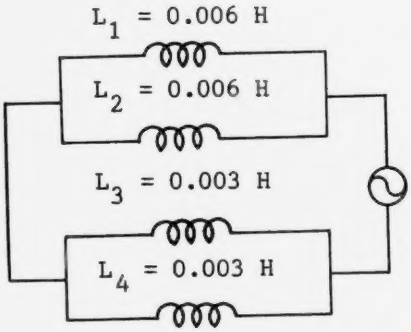
FF. E_T = 120 VAC

f = 400 Hz

L_T = _____

X_T = _____

I_T = _____



L_1 = 0.006 H
L_2 = 0.006 H
L_3 = 0.003 H
L_4 = 0.003 H

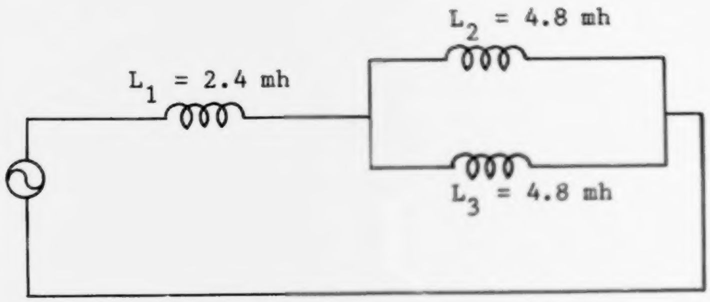
GG. E_T = 208 VAC

f = 400 Hz

L_T = ______

X_L = ______

I_T = ______


L_2 = 4.8 mh
L_1 = 2.4 mh
L_3 = 4.8 mh

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WORKBOOK SUPPLEMENT #4 - Determine Values in R-C Circuits

Apply the appropriate formulas for capacitors in series and parallel to answer the following questions. Show all work and record the correct values in the blanks provided.

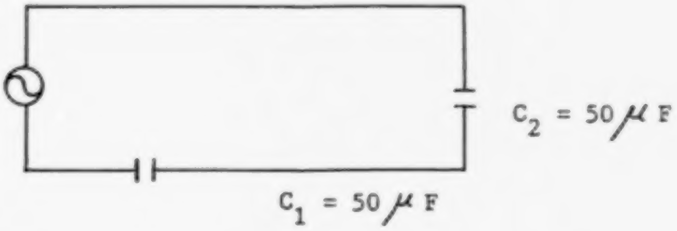
A. 120 VAC

60 cps

C_T = ______

X_C = ______

I_T = ______


$C_2 = 50\mu F$
$C_1 = 50\mu F$

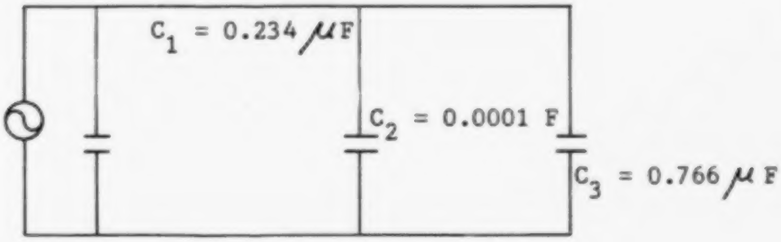
B. 120 VAC

60 Hz

C_T = ______

X_C = ______

I_T = ______


$C_1 = 0.234\mu F$
$C_2 = 0.0001\ F$
$C_3 = 0.766\mu F$

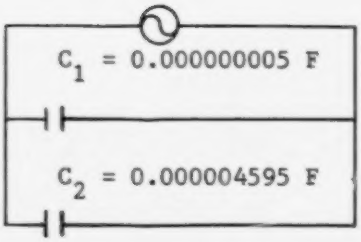
C. 120 VAC

400 Hz

C_T = ______

X_C = ______

I_T = ______


C_1 = 0.000000005 F
C_2 = 0.000004595 F

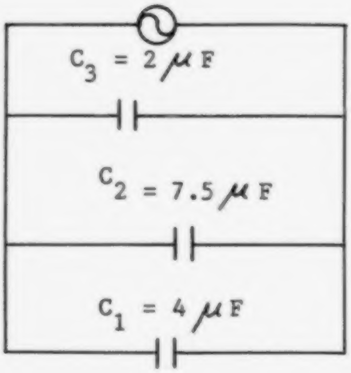
D. 120 VAC

400 cps

C_T = ______

X_C = ______

I_T = ______


$C_3 = 2\mu F$
$C_2 = 7.5\mu F$
$C_1 = 4\mu F$

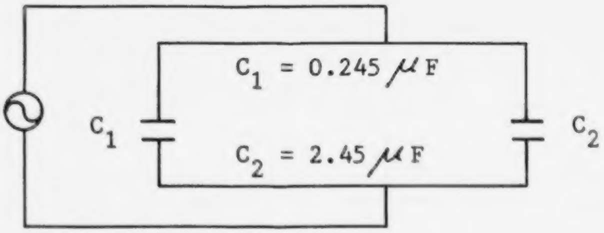
E. 200 VAC

60 Hz

C_T = ______

X_C = ______

I_T = ______


$C_1 = 0.245\ \mu F$
$C_2 = 2.45\ \mu F$
C_1
C_2

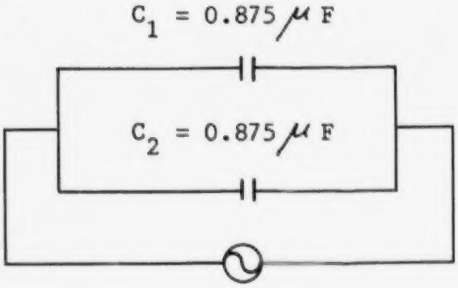
F. 120 VAC

400 Hz

C_T = ______

X_C = ______

I_T = ______


$C_1 = 0.875\ \mu F$
$C_2 = 0.875\ \mu F$

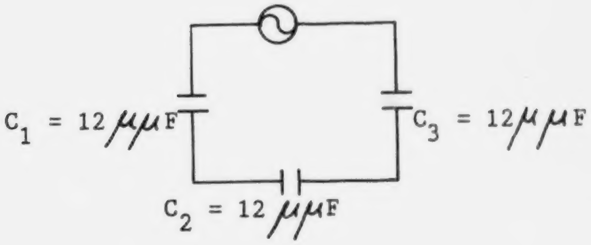
G. 200 VAC

200 MHz

C_T = ______

X_C = ______

I_T = ______


$C_1 = 12\mu\mu F$
$C_3 = 12\mu\mu F$
$C_2 = 12\mu\mu F$

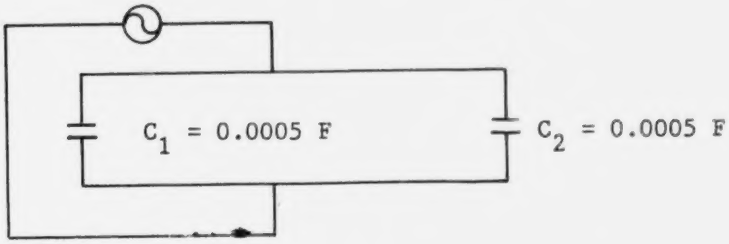
H. 120 VAC

60 Hz

C_T = ______

X_C = ______

I_T = ______


$C_1 = 0.0005$ F
$C_2 = 0.0005$ F

WORKBOOK SUPPLEMENT #4

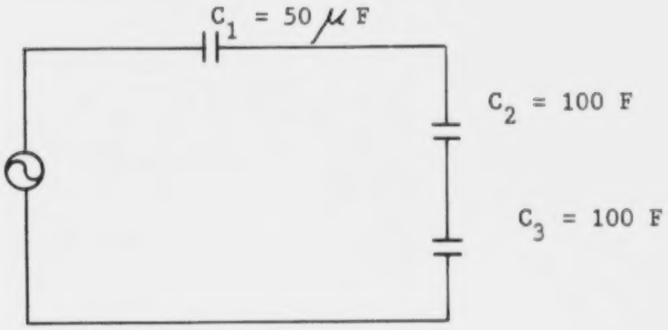
I. 120 VAC

400 cps

C_T = ______

X_C = ______

I_T = ______



$C_1 = 50\ \mu F$
$C_2 = 100\ F$
$C_3 = 100\ F$

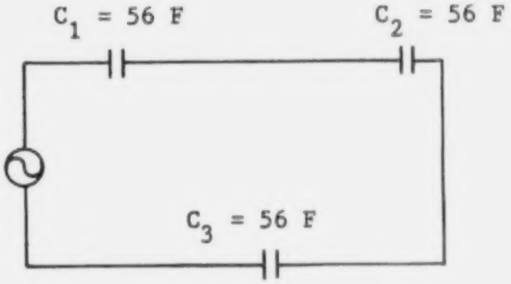
J. 120 VAC

400 Hz

C_T = ______

X_C = ______

I_T = ______



$C_1 = 56\ F$
$C_2 = 56\ F$
$C_3 = 56\ F$

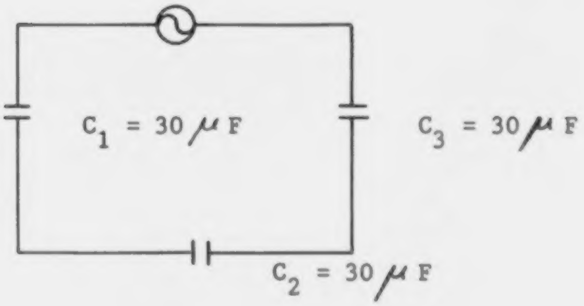
K. 400 VAC

60 cps

C_T = ______

X_C = ______

I_T = ______


C_1 = 30 μF
C_3 = 30 μF
C_2 = 30 μF

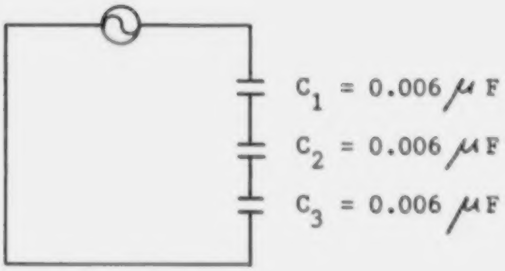
L. 120 VAC

2.2 kHz

C_T = ______

X_C = ______

I_T = ______


C_1 = 0.006 μF
C_2 = 0.006 μF
C_3 = 0.006 μF

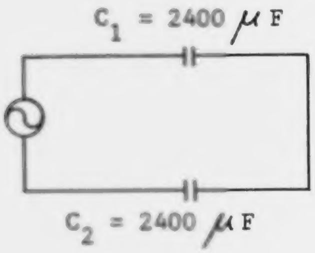
M. 200 VAC

60 Hz

C_T = ______

X_C = ______

I_T = ______


C_1 = 2400 μF
C_2 = 2400 μF

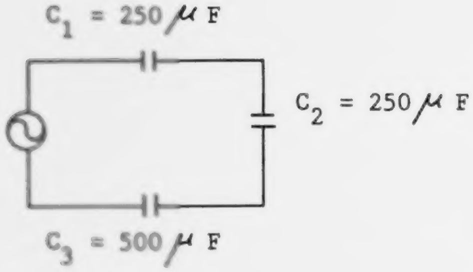
N. 120 VAC

400 Hz

C_T = ______

X_C = ______

I_T = ______


C_1 = 250 μF
C_2 = 250 μF
C_3 = 500 μF

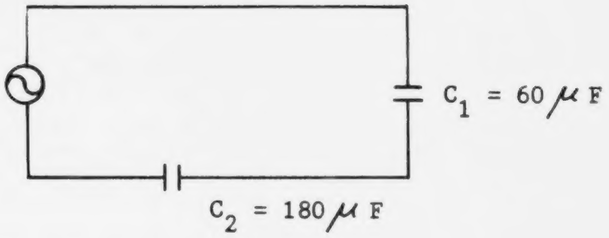
O. 120 VAC

60 Hz

C_T = ______

X_C = ______

I_T = ______


$C_1 = 60\mu F$
$C_2 = 180\mu F$

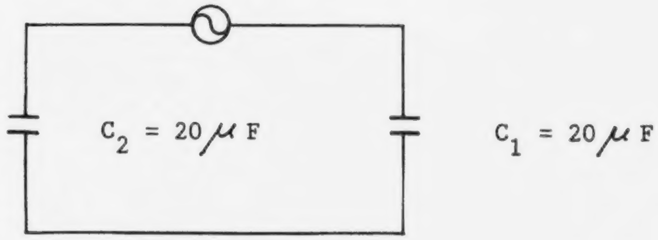
P. 200 VAC

60 cps

C_T = ______

X_C = ______

I_T = ______


$C_2 = 20\mu F$
$C_1 = 20\mu F$

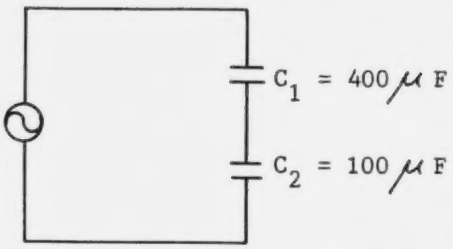
Q. 120 VAC

60 Hz

C_T = ______

X_C = ______

I_T = ______


C_1 = 400 μF
C_2 = 100 μF

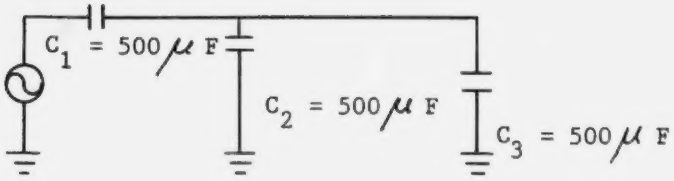
R. 120 VAC

60 Hz

C_T = ______

X_C = ______

I_T = ______


C_1 = 500 μF
C_2 = 500 μF
C_3 = 500 μF

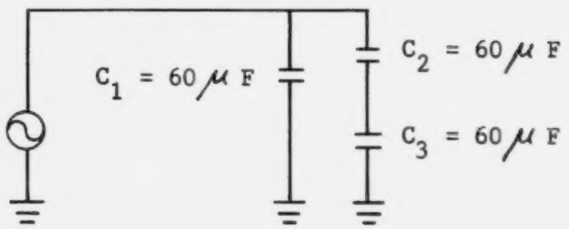
S. 120 VAC

400 cps

C_T = ______

X_C = ______

I_T = ______


$C_1 = 60\mu F$
$C_2 = 60\mu F$
$C_3 = 60\mu F$

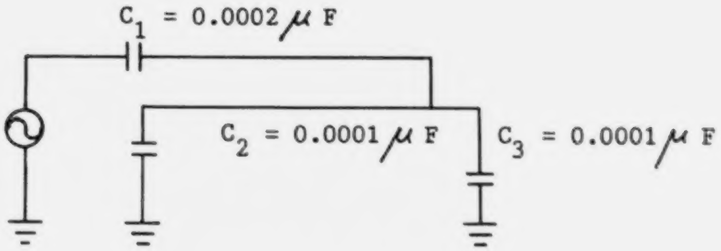
T. 120 VAC

2 MHz

C_T = ______

X_C = ______

I_T = ______


$C_1 = 0.0002\mu F$
$C_2 = 0.0001\mu F$
$C_3 = 0.0001\mu F$

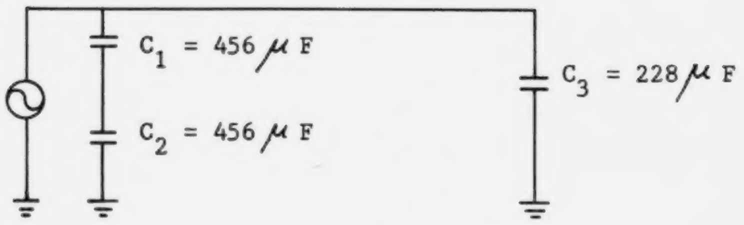
U. 120 VAC

400 cps

C_T = ______

X_C = ______

I_T = ______


$C_1 = 456 \mu F$
$C_2 = 456 \mu F$
$C_3 = 228 \mu F$

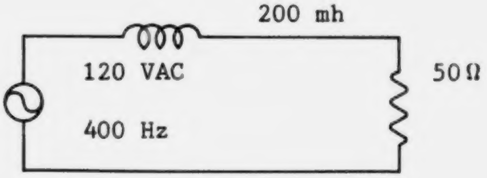
WORKBOOK SUPPLEMENT #5 - Determine Values in R-C-L Circuits

The following exercises will give you a brief review of R-L and R-C circuits, and will test your competency in determining values in R-C-L circuits. Show all work and record the correct values in the blanks provided.

A. X_L = _____

Z = _____

I = _____

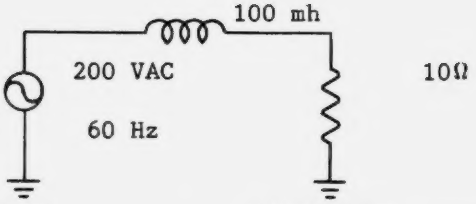


CURRENT WILL _________ VOLTAGE BY _________

B. X_L = _____

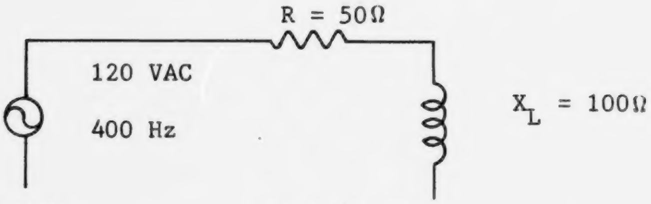
Z = _____

I = _____



CURRENT WILL _________ VOLTAGE BY _________

C. $Z =$ ______

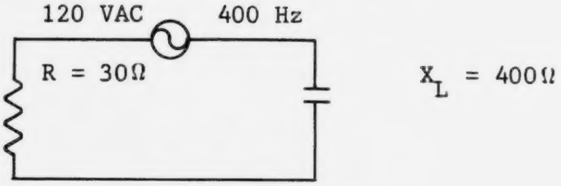

R = 50Ω
120 VAC
400 Hz
X_L = 100Ω

CURRENT WILL ________ VOLTAGE BY ________

D. $Z =$ ______

$I =$ ______

$X_C =$ ______

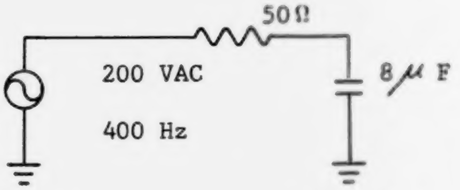

120 VAC
400 Hz
R = 30Ω
X_L = 400Ω

CURRENT WILL ________ VOLTAGE BY ________

E. X_C = ______

Z = ______

I = ______


50Ω
200 VAC
400 Hz
8μF

CURRENT WILL ________ VOLTAGE BY ________

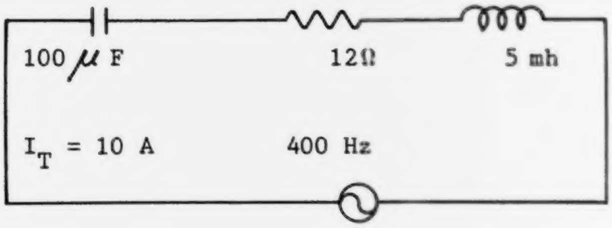
F. X_C = ______ (To nearest whole number)

X_L = ______ (To nearest whole number)

Z = ______

Applied voltage = ______

CURRENT WILL ________ VOLTAGE BY ________


100μF
12Ω
5 mh
I_T = 10 A
400 Hz

G. E_A = ______ I_T = ______

E_R = ______ I_R = ______

E_{X_C} = ______ I_{X_C} = ______

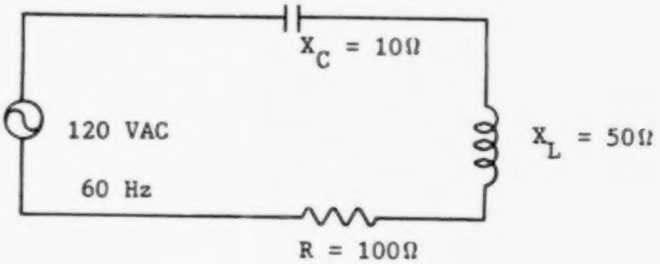
E_{X_L} = ______ I_{X_L} = ______

P_A = ______

P_T = ______

P.F. = ______

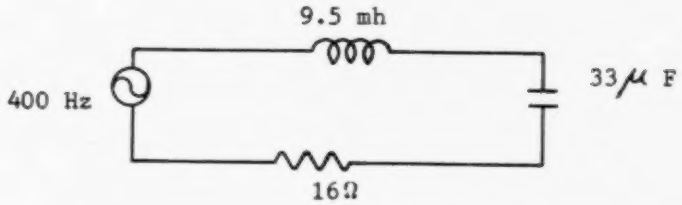
Z = ______


X_C = 10Ω
120 VAC
60 Hz
X_L = 50Ω
R = 100Ω

H. X_L = ______ (To nearest whole ohm)

X_C = ______ (To nearest whole ohm)

Z = ______


9.5 mh
400 Hz
33μ F
16Ω

WORKBOOK SUPPLEMENT #5

I. E_A = ______

E_R = ______

E_{X_C} = ______

E_{X_L} = ______

I_T = ______

I_R = ______

I_{X_C} = ______

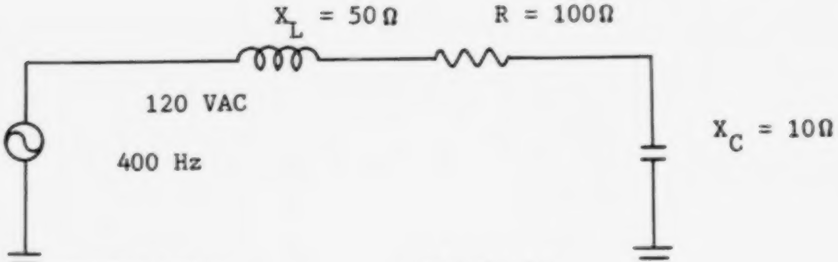
I_{X_L} = ______

P_A = ______

P_T = ______

P.F. = ______

Z = ______

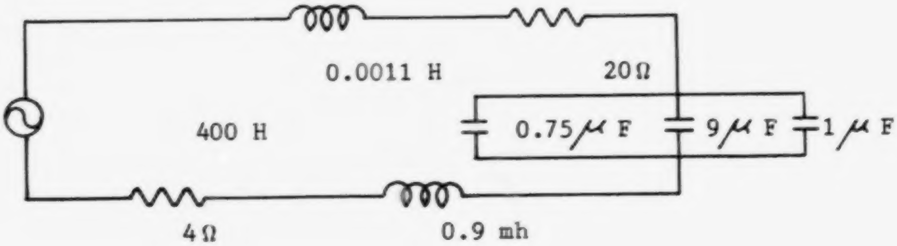

X_L = 50Ω
R = 100Ω
120 VAC
400 Hz
X_C = 10Ω

CURRENT WILL ________ VOLTAGE BY ________

J. X_L = ______

X_C = ______

Z = ______

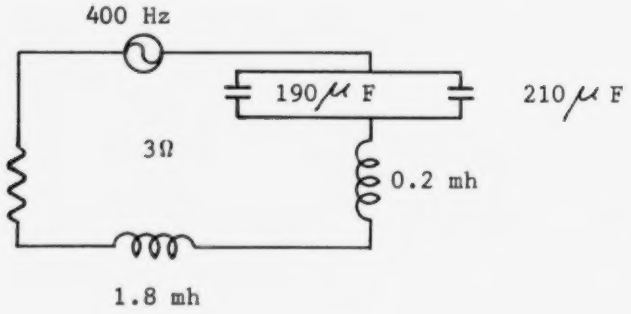

0.0011 H
20Ω
400 H
0.75μF
9μF
1μF
4Ω
0.9 mh

WORKBOOK SUPPLEMENT #5

K. X_L = ______

X_C = ______

Z = ______


400 Hz
190 µF
210 µF
3Ω
0.2 mh
1.8 mh

L. R_T = ______

C_T = ______

L_T = ______

X_L = ______

X_C = ______

E_A = ______

E_{X_L} = ______

E_{X_C} = ______

E_R = ______

I_T = ______

I_{X_L} = ______

I_{X_C} = ______

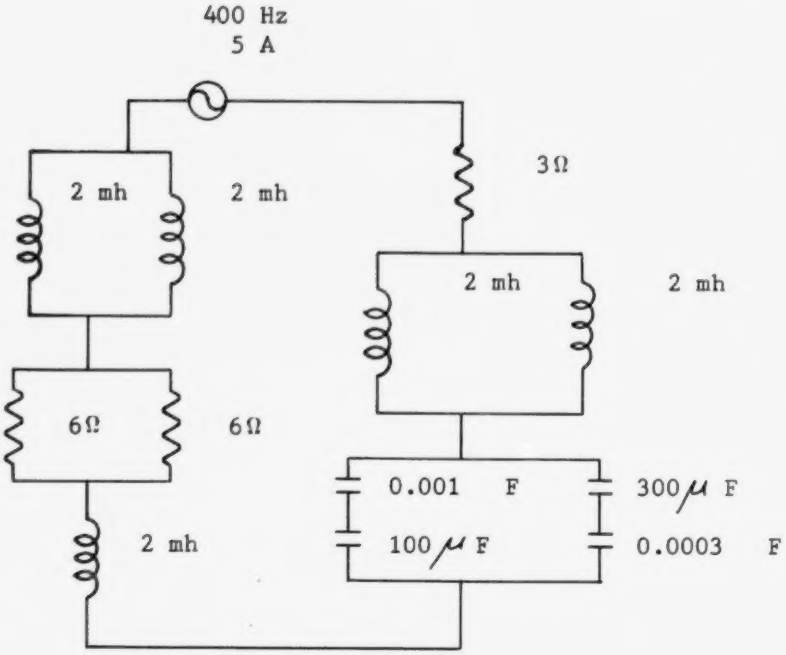
I_R = ______

Z = ______

P_A = ______

P_T = ______

P.F. = ______


400 Hz
5 A
2 mh
2 mh
3Ω
2 mh
2 mh
6Ω
6Ω
0.001 F
300 µF
2 mh
100 µF
0.0003 F

CURRENT WILL ________ VOLTAGE BY ________

GENERAL
G105 AVIATION ELECTRICITY AND ELECTRONICS
COMPUTE AND MEASURE CAPACITANCE AND INDUCTANCE
G105-B

ANSWERS TO WORKBOOK SUPPLEMENTS

Workbook Supplement #1

A. 30 V

B. 21.2 V Effective

C.
1. Effective
2. 400 V
3. 400 V

D. 480.76 peak-to-peak

E.
1. Cycle
2. One generator revolution
3. One alternation
4. Positive peak
5. Effective voltage (rms)
6. Average voltage
7. 0 - reference voltage
8. Negative peak
9. Peak-to-peak
10. Peak voltage or zero-to-peak

Workbook Supplement #2

A. $I_T = 6$ A
$R_T = 20\Omega$
$I_1 = 6$ A
$E_1 = 90$ V
$I_2 = 6$ A
$E_2 = 30$ V

B. $I_T = 4$ A
$R_T = 25\Omega$
$R_1 = 15\Omega$
$I_1 = 4$ A
$E_2 = 40$ V
$R_2 = 10\Omega$

C. $I_T = 10$ A
$R_T = 11\Omega$
$E_1 = 30$ V
$I_1 = 10$ A
$E_2 = 40$ V
$I_2 = 10$ A
$E_3 = 40$ V
$I_3 = 10$ A

D. $I_T = 4$ A
$R_T = 50\Omega$
$E_1 = 60$ V
$R_1 = 15\Omega$
$E_2 = 60$ V
$I_2 = 4$ A
$E_3 = 80$ V
$I_3 = 4$ A

E. $I_T = 11$ A
$R_T = 20\Omega$
$E_1 = 22$ V
$I_1 = 11$ A
$E_2 = 44$ V
$I_2 = 11$ A
$E_3 = 66$ V
$I_3 = 11$ A
$E_4 = 88$ V
$I_4 = 11$ A

F. $I_T = 4$ A
$R_T = 110\,\Omega$
$I_1 = 4$ A
$R_1 = 10\,\Omega$
$I_2 = 4$ A
$R_2 = 20\,\Omega$
$E_3 = 120$ V
$I_3 = 4$ A
$E_4 = 200$ V
$R_4 = 50\,\Omega$

G. $I_T = 15$ A
$R_T = 10\,\Omega$
$E_1 = 150$ V
$I_1 = 10$ A
$E_2 = 150$ V
$I_2 = 5$ A

H. $I_T = 20$ A
$E_1 = 100$ V
$I_1 = 10$ A
$E_2 = 100$ V
$I_2 = 10$ A
$R_2 = 10\,\Omega$

I. $I_T = 110$ A
$R_T = 1.09\,\Omega$
$E_1 = 120$ V
$I_1 = 60$ A
$E_2 = 120$ V
$I_2 = 30$ A
$E_3 = 120$ V
$I_3 = 20$ A

J. $R_T = 3\,\Omega$
$E_1 = 120$ V
$I_1 = 24$ A
$E_2 = 120$ V
$I_2 = 12$ A
$E_3 = 120$ V
$I_3 = 4$ A

Workbook Supplement #3

A. $L_T = 0.390$ H
$X_L = 147$

B. $L_T = 1.0$ H
$X_L = 2513$

C. $L_T = 1.0$ H
$X_L = 376.8$

D. $L_T = 10$ mh
$X_L = 37.7$

E. $L_T = 400$ mh
$X_L = 151$

F. $L_T = 10$ mh
$X_L = 25.12$

G. $L_T = 0.260$ H
$X_L = 653$

H. $L_T = 8.002$ H
$X_L = 20101$

I. $L_T = 4.0$ H
$X_L = 1507.2$
$I_T = 0.08$ A

J. $L_T = 2.0$ H
$X_L = 753.6$
$I_T = 0.159$ A

K. $L_T = 0.00276$ H
$X_L = 17.3$
$I_T = 1.16$ A

L. $L_T = 220$ mh
$X_L = 1381.6$
$I_T = 0.318$ A

M. $L_T = 40$ mh
$X_L = 100.48$
$I_T = 0.995$ A

ANSWERS TO WORKBOOK SUPPLEMENTS

N. $L_T = 0.14$ mh
$X_L = 879.2\,\Omega$
$I_T = 1$ A

O. $L_T = 20$ mh
$X_L = 7.54\,\Omega$
$I_T = 15.9$ A

P. $L_T = 0.53$ H
$X_L = 200\,\Omega$
$I_T = 0.6$ A

Q. $L_T = 0.1$ H
$X_L = 37.68\,\Omega$
$I_T = 3.18$ A

R. $L_T = 750$ mH
$X_L = 282.6\,\Omega$
$I_T = 1.557$ A

S. $L_T = 0.01$ H
$X_L = 25.12\,\Omega$
$I_T = 3.98$ A

T. $L_T = 13.3$ mh
$X_L = 25.05\,\Omega$
$I_T = 3.99$ A

U. $L_T = 1.09$ mh
$X_L = 164.28\,\Omega$
$I_T = 0.732$ A

V. $L_T = 0.5$ H
$X_L = 2512\,\Omega$
$I_T = 0.088$ A

W. $L_T = 20$ mh
$X_L = 50.24\,\Omega$
$I_T = 2.99$ A

X. $L_T = 0.012$ H
$X_L = 90.4\,\Omega$
$I_T = 1.99$ A

Y. $L_T = 0.017$ H
$X_L = 42.7\,\Omega$
$I_T = 10.3$ A

Z. $L_T = 0.5$ H
$X_L = 1256\,\Omega$
$I_T = 0.175$ A

AA. $L_T = 0.30$ H
$X_L = 188.4\,\Omega$
$I_T = 1.06$ A

BB. $L_T = 120$ mh
$X_L = 301\,\Omega$
$I_T = 0.399$ A

CC. $L_T = 200$ mh
$X_L = 1004.8\,\Omega$
$I_T = 0.199$ A

DD. $L_T = 0.3$ H
$X_L = 753.6\,\Omega$
$I_T = 0.199$ A

EE. $L_T = 0.678$ H
$X_L = 255.5\,\Omega$
$I_T = 1.957$ A

FF. $L_T = 0.0045$ H
$X_L = 11.3\,\Omega$
$I_T = 10.62$ A

GG. $L_T = 0.0048$ H
$X_L = 12.05\,\Omega$
$I_T = 17.26$ A

ANSWERS TO WORKBOOK SUPPLEMENTS

Workbook Supplement #4

A. $C_T = 25\,\mu F$
$X_C = 106\,\Omega$
$I_T = 1.132$ A

B. $C_T = 101\,\mu F$
$X_C = 26.2\,\Omega$
$I_T = 4.58$ A

C. $C_T = 4.6\,\mu F$
$X_C = 86.54\,\Omega$
$I_T = 1.39$ A

D. $C_T = 13.5\,\mu F$
$X_C = 29.5\,\Omega$
$I_T = 4.07$ A

E. $C_T = 2.695\,\mu F$
$L_C = 984.76\,\Omega$
$I_T = 0.203$ A

F. $C_T = 1.75\,\mu F$
$X_C = 227.5\,\Omega$
$I_T = 0.527$ A

G. $C_T = 4\,\mu\mu F$
$X_C = 199.04\,\Omega$
$I_T = 1.004$

H. $C_T = 0.001$ F
$X_C = 2.65\,\Omega$
$I_T = 45.28$ A

I. $C_T = 25\,\mu F$
$X_C = 15.92\,\Omega$
$I_T = 7.54$ A

J. $C_T = 18.67\,\mu F$
$X_C = 21.32\,\Omega$
$I_T = 5.63$ A

K. $C_T = 10\,\mu F$
$X_C = 265.4\,\Omega$
$I_T = 1.51$ A

L. $C_T = 0.002\,\mu F$
$X_C = 36189\,\Omega$
$I_T = 0.00332$ A

M. $C_T = 1200\,\mu F$
$X_C = 2.21\,\Omega$
$I_T = 90.43$ A

N. $C_T = 100\,\mu F$
$X_C = 3.98\,\Omega$
$I_T = 30.14$ A

O. $C_T = 45\,\mu F$
$X_C = 58.98\,\Omega$
$I_T = 2.03$ A

P. $C_T = 10\,\mu F$
$X_C = 265.4\,\Omega$
$I_T = 756.3$ mA

Q. $C_T = 80\,\mu F$
$X_C = 33.17\,\Omega$
$I_T = 3.62$ A

R. $C_T = 333\,\mu F$
$X_C = 7.97\,\Omega$
$I_T = 15.06$ A

S. $C_T = 90\,\mu F$
$X_C = 4.42\,\Omega$
$I_T = 27.13$ A

T. $C_T = 0.0001\,\mu F$
$X_C = 796\,\Omega$
$I_T = 0.151$ A

U. $C_T = 456\,\mu F$
$X_C = 0.873\,\Omega$
$I_T = 137.46$ A

ANSWERS TO WORKBOOK SUPPLEMENTS

Workbook Supplement #5

A. $X_L = 502.4\Omega$
$Z = 504.88\Omega$
$I = 0.238$ A
LAG; 84.3°

B. $X_L = 37.68\Omega$
$Z = 39\Omega$
$I = 5.13$ A
LAG; 75.1°

C. $Z = 111.8\Omega$
LAG; 63.4°

D. $Z = 401\Omega$
$I = 0.299$ A
$X_C = 400\Omega$
LEAD; 85.7°

E. $X_C = 49.7\Omega$
$Z = 70.5\Omega$
$I = 2.84$ A
LEAD; 44.8°

F. $X_C = 4\Omega$
$X_L = 13\Omega$
$Z = 15\Omega$
Applied voltage = 150 V
LAG; 36.9°

G. $E_A = 120$ V
$E_R = 111$ V
$E_{X_C} = 11.1$ V
$E_{X_L} = 55.5$ V

$I_T = 1.11$ A
$I_R = 1.11$ A
$I_{X_C} = 1.11$ A
$I_{X_L} = 1.11$ A

$P_A = 133.2$ VAR
$P_T = 123.21$ W
P.F. = 0.92592
$Z = 108\Omega$

H. $X_L = 24\Omega$
$X_C = 12\Omega$
$Z = 20\Omega$

I. $E_A = 120$ V
$E_R = 111$ V
$E_{X_C} = 11.1$ V
$E_{X_L} = 55.5$ V
LAG; 21.8°

$I_T = 1.11$ A
$I_R = 1.11$ A
$I_{X_C} = 1.11$ A
$I_{X_L} = 1.11$ A

$P_A = 133.2$ VAR
$P_T = 123.21$ W
P.F. = 0.92592
$Z = 108\Omega$

ANSWERS TO WORKBOOK SUPPLEMENTS

J. $X_L = 5.02\Omega$
$X_C = 36.5\Omega$
$A = 40\Omega$

K. $X_L = 5\Omega$
$X_C = 0.996\Omega$
$Z = 5\Omega$

L. $R_T = 6\Omega$
$C_T = 0.0002$ F
$L_T = 0.004$ H
$X_L = 10.0\Omega$
$X_C = 2\Omega$
$E_A = 50$ V
$E_{X_L} = 50$ V
$E_{X_C} = 10$ V
$E_R = 30$ V
$I_T = 5$ A
$I_{X_L} = 5$ A
$I_{X_C} = 5$ A
$I_R = 5$ A
$Z = 10\Omega$
$P_A = 250$ VAR
$P_T = 150$ W
P.F. = 0.6
LAG; 53.1°

GENERAL
G105 AVIATION ELECTRICITY AND ELECTRONICS
COMPUTE AND MEASURE CAPACITANCE AND INDUCTANCE
G105-B

THEORY TEST

1. Match terms related to AC electricity to their correct definitions. Write the correct numbers in the blanks.

_____a. Device used to store an electrical charge in a circuit, composed of two or more sets of plates, separated by a nonconducting material called a dielectric

_____b. Product of voltage and amperage in an AC circuit, with no consideration of the power factor for the phase angle

_____c. Winding of wire designed for use in a circuit to produce an electromagnetic field or to produce inductance

_____d. Part of an AC cycle during which current is flowing in one direction; one half of a cycle

_____e. Opposition to the flow of alternating current offered by a capacitor

_____f. One complete positive and one complete negative alternation of alternating current or voltage

_____g. Maximum instantaneous value of an alternating current or voltage, measured in either the positive or negative direction

_____h. Ability of a capacitor to oppose any change in voltage, or ability of an electrical device to store a charge of electricity

_____i. Electric current which periodically changes in direction and constantly changes in magnitude

1. Coil
2. Capacitor
3. Capacitive reactance
4. Cycle
5. Alternation
6. Apparent power
7. Capacitance
8. Alternating current
9. Amplitude

____j. Rectifier which uses both the positive and negative alternations of AC to produce pulsating direct current

____k. Value of AC which will give an equal heating effect as DC, equal to 0.707 times the peak value

____l. Number of complete cycles per second

____m. Force in space which exerts an equivalent force on an electrical charge within its region of influence

____n. Total opposition to alternating current when the opposition consists of any combination of resistance, inductive reactance, and capacitive reactance, measured in ohms

____o. Basic unit of measure of capacitance; ability of a capacitor to store one coulomb of electricity for each volt applied across its plates

____p. Opposition to the flow of alternating current caused by the inductance of a circuit

____q. Property of a coil to oppose any change in current flow

____r. Process of charging an object electrically by placing it in an electric field

____s. Instrument for measuring the cycles per second of an alternating current or voltage

____t. Basic unit of measure for inductance

____u. Common unit of mechanical power, equivalent of raising 33,000 pounds one foot in one minute, or 550 pounds one foot in one second

10. Farad
11. Electrostatic field
12. Inductance
13. Full-wave rectifier
14. Henry
15. Effective value
16. Frequency
17. Horsepower
18. Impedance
19. Electrostatic induction
20. Frequency meter
21. Inductive reactance

THEORY TEST

____ v. Device which causes inductance

____ w. Circuit that contains resistance, capacitance, and inductance

____ x. Condition that exists when two waves of the same frequency pass through their maximum and minimum values at the same time

____ y. Amount one wave is ahead of another in time, expressed in electrical degrees

____ z. Unit of measure used to designate true power

____ aa. Unit of measure used to designate reactive power

____ bb. Unit of measure used to designate apparent power

____ cc. Circuit property existing when the position of two coils causes the magnetic lines of force from one coil to link with the turns of the other coil and induce an EMF

____ dd. Amount one wave is behind another in time, expressed in electrical degrees

____ ee. Current which changes in amplitude but flows in only one direction

____ ff. Time in electrical degrees by which one wave leads or lags another

____ gg. Greatest value reached during an alternation

____ hh. Circuit that contains capacitance and resistance

____ ii. Time relationship between alternating voltages or currents

____ jj. Ratio of true power to apparent power of an AC circuit

22. Pulsating direct current
23. R-C-L circuit
24. Power factor
25. Mutual induction
26. Phase angle
27. Lead
28. Lag
29. Kilowatt
30. In-phase
31. Inductor
32. Kilovolt ampere reactance
33. Peak value
34. R-C circuit
35. Phase
36. Kilovolt ampere

____kk. Opposition to the flow of alternating current offered by inductance, capacitance, or both

____ll. Power consumed by resistance in a circuit

____mm. Load in which the current is not in phase with the applied voltage; a capacitive or an inductive load

____nn. Product of current and voltage in an AC circuit

____oo. Component which introduces reactance into a circuit

____pp. Circuit that is energized by a single alternating current

____qq. Alternating current system in which there are three separate voltages and currents at one time

____rr. Device which changes alternating current into direct current

____ss. Line used to represent both direction and magnitude

____tt. Circuit that contains resistance and inductance

____uu. Graph of one cycle of alternating current or voltage

____vv. Basic unit of measurement of electrical pressure; the EMF required to cause one ampere of current to flow through one ohm of resistance

____ww. Circuit in which current and voltage are in-phase; capacitive reactance is equal to inductive reactance, true power is equal to apparent power, and phase angle is zero

37. Volt-amp
38. Sine-wave
39. Resonant circuit
40. Three-phase
41. R-L circuit
42. Reactive load
43. True power
44. Single-phase
45. Reactor
46. Rectifier
47. Reactance
48. Volt
49. Vector

2. State the relationship between peak, peak-to-peak, average, and rms voltage.

   a. Rms voltage may be determined by taking peak voltage and

   ----

   b. Peak-to-peak voltage may be obtained by taking peak voltage and

   ----

   c. Peak voltage may be obtained by taking rms voltage and

   ----

   d. Average voltage may be obtained by taking peak voltage and

   ----

3. Determine current, resistance, voltage, and power in the resistive AC circuits shown below. Write the correct answers in the blanks provided.

   a. E_T = ______

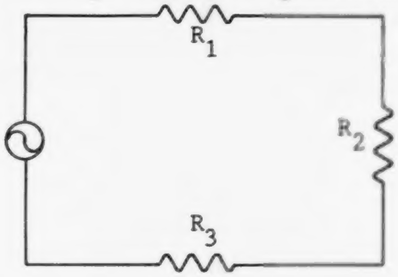
   I_T = 2 A

   R_T = ______

   P_T = ______

   E_1 = 40 V R_1 = ____

   I_1 = ____ P_1 = ____



E_2 = ____ R_2 = 30Ω

I_2 = ____ P_2 = ____

E_3 = ____ R_3 = ____

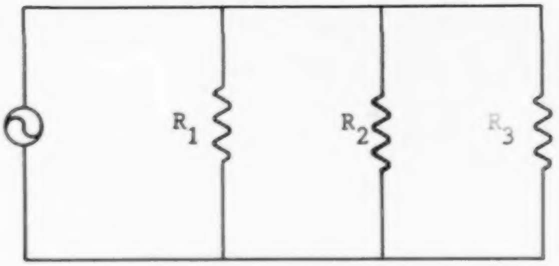
I_3 = ____ P_3 = 100 w

b. E_T = 100 V E_1 = ____ R_1 = 200 Ω

I_T = ______ I_1 = _____ P_1 = ____

R_T = _______

P_T = _______



E_3 = ____

I_3 = _____

R_3 = 50 Ω

P_3 = ____

E_2 = _____ R_2 = 100 Ω

I_2 = _____ P_2 = _____

THEORY TEST

4. Identify the following basic AC electrical symbols by writing the corresponding terms in the blanks.

a. L ____________________

b. R ____________________

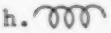
c. F ____________________

d. X_L ____________________

e. ____________________

f. P_T ____________________

g. Z ____________________

h.  ____________________

i. Hz ____________________

j. X_C ____________________

k. X ____________________

l. kHz ____________________

m. Mh ____________________

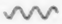
n. μμF ____________________

o. mh ____________________

p. Ø ____________________

q. VAC ____________________

r. H ____________________

s.  ____________________

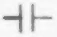
t. cps ____________________

u. f ____________________

v. P_A ____________________

w. P.F. ____________________

x. C ____________________

y.  ____________________

z. VAR ____________________

aa. kw ____________________

bb. μF ____________________

cc. MHz ____________________

dd. KVAR ____________________

5. Select true statements related to the principle of operation of an inductor. Circle the letter preceding each correct answer.

a. When an alternating current flows through a coil of wire, the rise and fall of the current flow, first in one direction, and then in another, sets up an expanding and collapsing magnetic field about the coil.

b. A voltage is induced in the coil which is opposite in direction to the applied voltage and which opposes any change in the alternating current.

c. Increasing the inductance of a coil will increase the amount of AC that can flow through it.

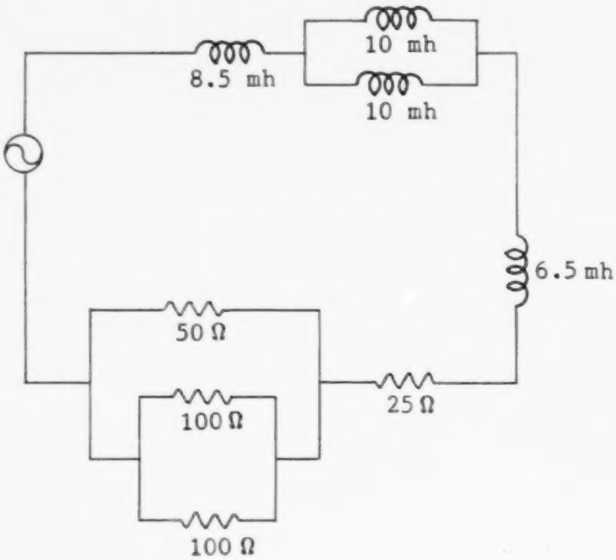
d. Inductive reactance increases as the frequency increases.

e. The strength of a magnetic field surrounding a conductor is determined by the amount of voltage.

6. Determine current, resistance, inductance, inductive reactance, impedance, power factor, phase angle, true power, and apparent power in the following R-L circuits. Write the correct answers in the blanks provided.

a. 120 VAC
400 Hz

L_T = ______ P.F. = ______
X_L = ______ I_T = ______
R_T = ______ P_A = ______
Z = ______ P_T = ______
ϕ = ______

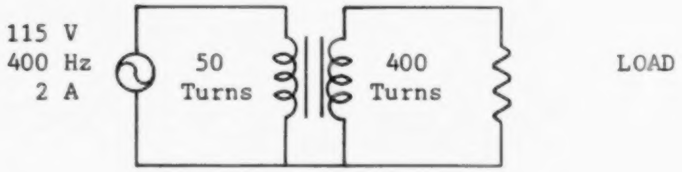


10 mh
8.5 mh
10 mh
6.5 mh
50 Ω
25 Ω
100 Ω
100 Ω

b. (Same circuit as above)
120 VAC
2 kHz

L_T = ______ P.F. = ______
X_L = ______ I_T = ______
R_T = ______ P_A = ______
Z = ______ P_T = ______
ϕ = ______

7. Determine values for voltage and current in the secondary windings of a transformer. In the following circuits, find the correct values of voltage and current and write them in the blanks provided.



115 V
400 Hz
2 A
50 Turns
400 Turns
LOAD

E = ______________________________ I. = ______________________________

8. Select true statements related to the principle of operation of a capacitor. Circle the letter preceding each correct answer.

   a. A capacitor is composed of two conductors separated by a dielectric.

   b. A capacitor with a thin dielectric has less capacity than the same capacitor with a thick dielectric.

   c. When voltage is applied to the capacitor, the plates become charged and energy is stored in the newly created electrostatic field.

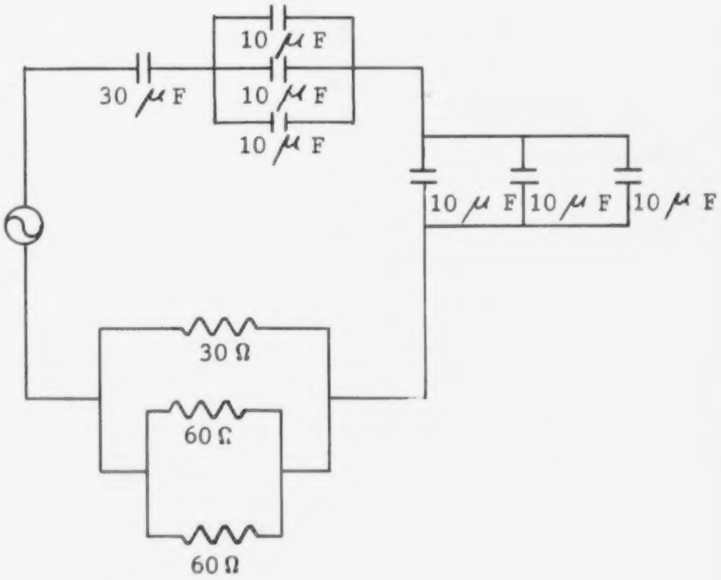
   d. Current flows only when the capacitor is charging or discharging.

   e. Electrical energy is stored in a capacitor in electromagnetic fields.

9. Determine current, resistance, capacitance, capacitive reactance, impedance, power factor, phase angle, true power, and apparent power in the following R-C circuit. Write the correct answers in the blanks provided.

   a. 400 Hz
   120 VAC

   C_T = ______ Ø = ______
   R_T = ______ P.F. = ______
   X_C = ______ P_A = ______
   Z = ______ P_T = ______
   I_T = ______



   b. (Same circuit as above)
   2 kHz
   120 VAC

   C_T = ______ Ø = ______
   R_T = ______ P.F. = ______
   X_C = ______ P_A = ______
   Z = ______ P_T = ______
   I_T = ______

10. Determine current, resistance, capacitance, capacitive reactance, power factor, phase angle, true power, apparent power, impedance, inductance, and inductive reactance in the following R-C-L circuit. Write the correct answers in the blanks provided.

a. 400 Hz
120 VAC

L_T = ______ ϕ = ______

C_T = ______ P.F. = ______

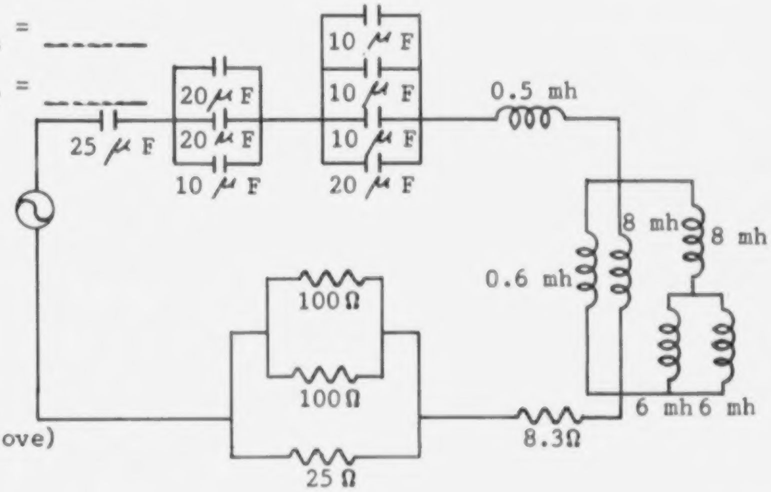
R_T = ______ P_A = ______

X_L = ______ P_T = ______

X_C = ______

I_T = ______

Z = ______


10 µF
10 µF
10 µF
20 µF
20µF
20 µF
10 µF
25 µF
0.5 mh
8 mh
8 mh
0.6 mh
6 mh
6 mh
100 Ω
100 Ω
25 Ω
8.3Ω

b. (Same circuit as above)
2 kHz
120 VAC

L_T = ______ ϕ = ______

C_T = ______ P.F. = ______

R_T = ______ P_A = ______

X_L = ______ P_T = ______

X_C = ______

Z = ______

I_T = ______

11. In the previous problem, determine the resonant frequency for the given circuit and write the correct answer in the blank.____________________

GENERAL
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COMPUTE AND MEASURE CAPACITANCE AND INDUCTANCE
G105-B

ANSWERS TO THEORY TEST

1. a. 2
b. 6
c. 1
d. 5
e. 3
f. 4
g. 9
h. 7
i. 8
j. 13
k. 15
l. 16
m. 11
n. 18
o. 10
p. 21
q. 12
r. 19
s. 20
t. 14
u. 17
v. 31
w. 23
x. 30
y. 27
z. 29
aa. 32
bb. 36
cc. 25
dd. 28
ee. 22
ff. 26
gg. 33
hh. 34
ii. 35
jj. 24
kk. 47
ll. 43
mm. 42
nn. 37
oo. 45
pp. 44
qq. 40
rr. 46
ss. 49
tt. 41
uu. 38
vv. 48
ww. 39

2. a. Multiplying by 0.707
b. Multiplying by two
c. Dividing by 0.707
d. Multiplying by 0.637

3. a. $E_T = 150$ V
$R_T = 75\Omega$
$P_T = 300$ W
$I_1 = 2$ A
$R_1 = 20\Omega$
$P_1 = 80$ W
$E_2 = 60$ V
$I_2 = 2$ A
$P_2 = 120$ W
$E_3 = 50$ V
$I_3 = 2$ A
$R_3 = 25\Omega$

b. $I_T = 3.5$ A
$R_T = 28.57\Omega$
$P_T = 350$ W
$E_1 = 100$ V
$I_1 = 0.5$ A
$P_1 = 50$ W
$E_2 = 100$ V
$I_2 = 1$ A
$P_2 = 100$ W
$E_3 = 100$ V
$I_3 = 2$ A
$R_3 = 200$ W

4. a. Inductance
b. Resistance
c. Farad
d. Inductive reactance
e. AC source
f. True power
g. Impedance
h. Inductor
i. Hertz
j. Capacitive reactance
k. Reactance
l. Kilohertz
m. Megahenry
n. Picofarad
o. Millihenry
p. Phase angle
q. Volts alternating current
r. Henry
s. Resistor
t. Cycles per second
u. Frequency
v. Apparent power
w. Power factor
x. Capacitance
y. Capacitor
z. Volt-amps reactive
aa. Kilowatt
bb. Microfarad
cc. Megahertz
dd. Kilovolt ampere reactance

ANSWERS TO THEORY TEST

5. a, b, d

6. a.
$L_T = 20$ mh
$X_L = 50.26\,\Omega$
$R_T = 50\,\Omega$
$Z_T = 70.89\,\Omega$
$= 45^\circ$ ELI
P.F. = 0.71
$I_T = 1.69$ A
$P_A = 202.80$ VAR
$P_T = 143.98$ W

b.
$L_T = 20$ mh
$X_L = 251.2\,\Omega$
$R_T = 50\,\Omega$
$Z_T = 246.2\,\Omega$
$= 12^\circ$ ELI
P.F. = 0.203
$I_T = 0.49$ A
$P_A = 58.8$ VAR
$P_T = 11.76$ W

7. E = 920 V I = 0.25 A (250 mA)

8. a, c, d

9. a.
$C_T = 10\,\mu F$
$R_T = 15\,\Omega$
$X_C = 39.8\,\Omega$
$Z = 42.5\,\Omega$
$I_T = 2.8$ A
$\phi = 69^\circ$ ICE
P.F. = 0.35
$P_A = 33^\circ$ VAR
$P_T = 119.5$ W

b.
$C_T = 10\,\mu F$
$R_T = 15\,\Omega$
$X_C = 7.9\,\Omega$
$Z = 16.9\,\Omega$
$I_T = 7$ A
$\phi = 27^\circ$ ICE
P.F. = 0.88
$P_A = 849$ VAR
$P_T = 748$ W

10. a.
$L_T = 1.02$ mh
$C_T = 12.5\,\mu F$
$R_T = 25\,\Omega$
$X_L = 2.56\,\Omega$
$X_C = 31.8\,\Omega$
$I_T = 3.12$ A
$Z_T = 38.5\,\Omega$
$\phi = 41^\circ$ ICE
P.F. = 0.65
$P_A = 374.4$ VAR
$P_T = 243.36$ W

b.
$L_T = 1.02$ mh
$C_T = 12.5\,\mu F$
$R_T = 25\,\Omega$
$X_L = 12.8\,\Omega$
$X_C = 6.3\,\Omega$
$Z = 25.8\,\Omega$
$I_T = 4.6$ A
$\phi = 14.8^\circ$ ELI
P.F. = 0.96
$P_A = 556.8$ VAR
$P_T = 439$ W

11. 1410 ± 20 Hz

MODULE OF INSTRUCTION
FOR
AVIATION MAINTENANCE TECHNOLOGY

GENERAL
G105 AVIATION ELECTRICITY AND ELECTRONICS
MEASURE VOLTAGE, CURRENT, RESISTANCE, AND CONTINUITY
G105-C

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G105 AVIATION ELECTRICITY AND ELECTRONICS
MEASURE VOLTAGE, CURRENT, RESISTANCE, AND CONTINUITY
G105-C

MODULE CONTENTS

A. Introduction and Module Objective

B. Specific Objectives

C. Instructor's Module Implementation Guide

  1. Instructional Supplement #1--Project Board Box Instructions

D. Technical Information Supplements

  1. Technical Information Supplement #1--Proper Connection of a Voltmeter
  2. Technical Information Supplement #2--Proper Connection of an Ohmmeter
  3. Technical Information Supplement #3--Proper Connection of an Ammeter
  4. Technical Information Supplement #4--Interpret the Scales of a Multimeter
  5. Technical Information Supplement #5--The Digital Multimeter

E. Transparency Masters

  1. TM #1--Parts of A Multimeter
  2. TM #2--Parts of a Digital Multimeter
  3. TM #3--Example of a Project Board (Breadboard)

F. Workbook Supplements

  1. Workbook Supplement #1--Read the Multimeter
  2. Workbook Supplement #2--Analyze an Electrical Circuit Diagram Showing Multimeter Connections

G. Answers to Workbook Supplements

H. Project Guides

  1. Project Guide #1--Construct a Circuit from a Schematic Diagram
  2. Project Guide #2--Determine Continuity of a Circuit
  3. Project Guide #3--Analyze Resistors in a Circuit

MODULE CONTENTS

   4. Project Guide #4--Measure Direct Current Voltage
   5. Project Guide #5--Measure Direct Current
   6. Project Guide #6--Perform Circuit Analysis Using Ohm's Law
   7. Project Guide #7--Perform Series Circuit Analysis Using Electrical Measuring Devices
   8. Project Guide #8--Perform Parallel Circuit Analysis Using Electrical Measuring Devices

I. Theory Test

J. Answers to Theory Test

MEASURE VOLTAGE, CURRENT, RESISTANCE, AND CONTINUITY

G105-C

INTRODUCTION

Anyone concerned with aircraft maintenance is aware of the increasing use of electricity in modern systems and recognizes the importance to the mechanic of a thorough understanding of electrical principles and the devices used to measure and diagnose electrical circuits. As an aviation maintenance technician, you will be required to troubleshoot electrical circuits. Therefore, it is necessary for you to develop competency in reading and interpreting electrical measuring devices.

MODULE OBJECTIVE

After completion of this module, you will be able to use electrical measuring devices to analyze and troubleshoot electrical circuits. You will also be able to interpret basic electrical symbols used in electrical diagrams. You will demonstrate this knowledge by completing the procedures outlined in the workbook assignments and project guides and by scoring a minimum of 85 percent on the module theory test.

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MEASURE VOLTAGE, CURRENT, RESISTANCE, AND CONTINUITY
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SPECIFIC OBJECTIVES

After completion of this module, you will be able to:

1.	State Ohmn's law. (1)	EA-ITP-G	2:VII:19
2.	State the principle of Kirchhoff's voltage law. (1)	EA-ITP-G	2:IX:29
3.	State the principle of Kirchhoff's current law. (1)	EA-ITP-G	2:IX:30
4.	Arrange in order the steps for properly connecting a voltmeter. (2)	Technical Supplement #1	
5.	Arrange in order the steps for properly connecting an ohmmeter. (2)	Technical Supplement #2	
6.	Arrange in order the steps for properly connecting an ammeter. (2)	Technical Supplement #3	
7.	Interpret the scales of a multimeter. (2)	Technical Supplement #4 Workbook Supplement #1	
8.	Select true statements related to the digital multimeter. (1)	Technical Supplement #5	
9.	Analyze an electrical circuit diagram, using Ohm's law and Kirchhoff's current and voltage laws. (2)	Workbook Supplement #2	
10.	Construct a circuit from a schematic diagram. (3)	Project Guide #1	
11.	Determine continuity of a circuit. (3)	Project Guide #2	
12.	Analyze resistors in a circuit. (3)	Project Guide #3	
13.	Measure direct current voltage. (3)	Project Guide #4	
14.	Measure direct current. (3)	Project Guide #5	
15.	Perform circuit analysis using Ohm's law. (3)	Project Guide #6	

SPECIFIC OBJECTIVES

16. Perform series circuit analysis using electrical measuring devices. (3)	Project Guide #7
17. Perform parallel circuit analysis using electrical measuring devices. (3)	Project Guide #8

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INSTRUCTOR'S MODULE IMPLEMENTATION GUIDE

I. Implementation Suggestions

(NOTE: Have students read all materials related to the Specific Objectives. Much of this reading can be done as homework assignments.)

(NOTE: It will be necessary for each student to have a multimeter.)

Estimated Teaching Time		Theory	Lab
Objective 1	Review Ohm's law. Discuss the relationship of each component. Explain how when the factor (E, I, or R) changes, the other factors will also change.		
Objective 2	Discuss Kirchhoff's law of voltage.		
Objective 3	Study the characteristics of Kirchhoff's law of current.		
Objective 4	Discuss and demonstrate how to set meter on a volt scale, using Technical Information Supplement #1. Explain that the voltmeter is connected in parallel with power ON. Show Transparency Master #1. Have students set meter to volt scale.		
Objective 5	Discuss and demonstrate how to set meter on an ohm scale, using Technical Information Supplement #2. Explain that the ohmmeter is connected in series with circuit power OFF. Show Transparency Master #1. Have students set meter to volt scale.		
Objective 6	Discuss and demonstrate how to set meter on an amp scale, using Technical Information Supplement #3. Explain that the ammeter is connected in series. Emphasize that the ammeter system power must be ON for an ammeter to be read. Show Transparency Master #1. Have students set meter on an amp scale.		

Estimated Teaching Time		Theory	Lab
Objective 7	Have students read Technical Information Supplement #4. Have students complete Workbook Supplement #1.		
Objective 8	Discuss and demonstrate how to use the digital multimeter. Use Technical Information Supplement #5 and Transparency Master #2. Allow the student to work with digital multimeter. The digital multimeter could be used to complete one of the project guides.		
Objective 9	Have students review symbols from G105-A and then analyze a series-parallel circuit, using Ohm's law and Kirchhoff's laws. Have students complete Workbook Supplement #2.		
Objective 10	Explain to students the purpose of using the project board and the importance of being able to perform the various project guides that will be completed. Go over the components included in the project board box, using Instructional Supplement #1. Show Transparency Master #3. Assign Project Guide #1 and monitor students as they complete the exercise. Explain that the answers or solutions to each project are at the discretion of the instructor. Students must be signed off by instructor before advancing to the next project.		
Objective 11	Assign Project Guide #2. Assist students as necessary.		
Objective 12	Assign Project Guide #3. Assist students as necessary.		
Objective 13	Assign Project Guide #4. Assist students as necessary.		
Objective 14	Assign Project Guide #5. Assist students as necessary.		
Objective 15	Assign Project Guide #6. Assist students as necessary.		

INSTRUCTOR'S MODULE IMPLEMENTATION GUIDE

Estimated Teaching Time		Theory	Lab
Objective 16	Assign Project Guide #7. Assist students as necessary.		
Objective 17	Assign Project Guide #8. Assist students as necessary.		

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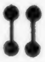
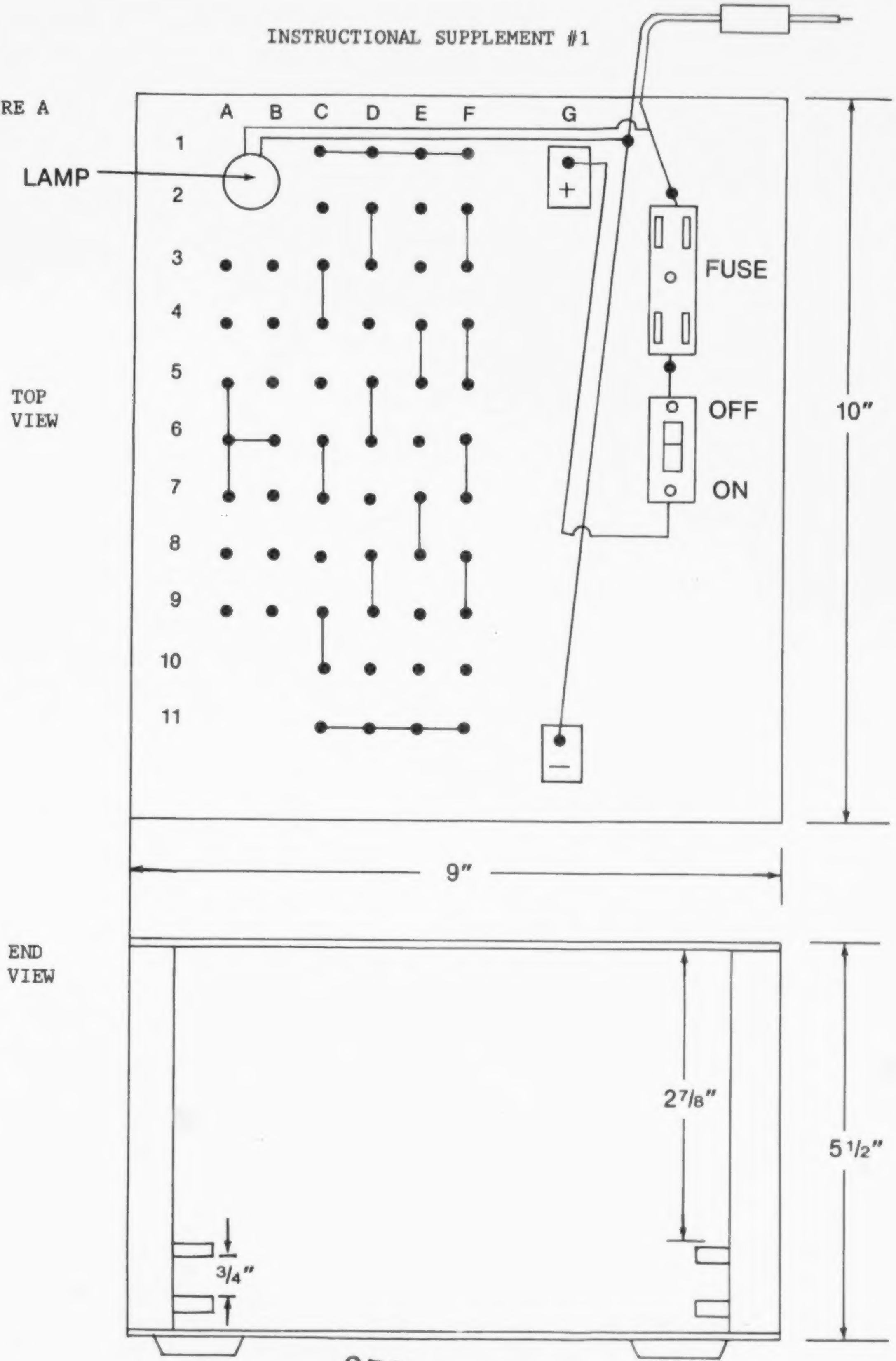
INSTRUCTIONAL SUPPLEMENT #1--Project Board Box Instructions

A. Make the project board box from nonconducting material, using the drawing as a guide. Pins must be placed 3/4 inch apart, measured from center to center. (See Figure A on next page.)

(NOTE:  = electrical connection under board.)

INSTRUCTIONAL SUPPLEMENT #1

FIGURE A

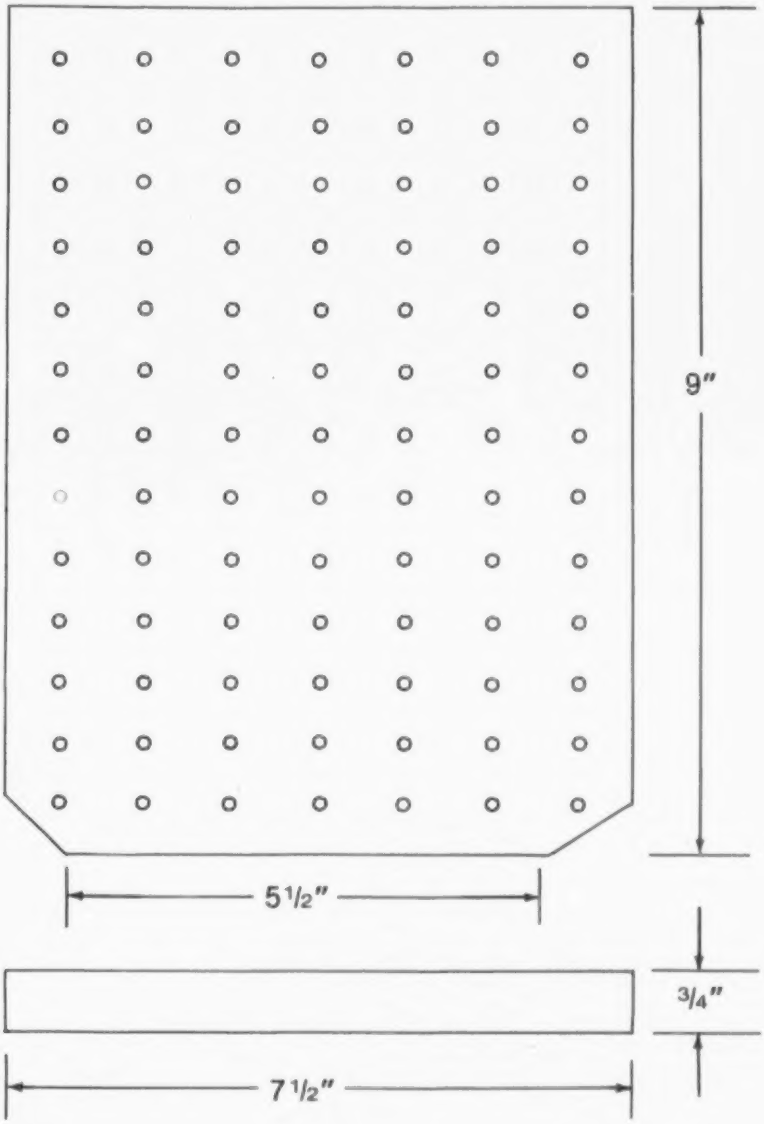

A
B
C
D
E
F
G
1
2
3
4
5
6
7
8
9
10
11
LAMP
+
FUSE
OFF
ON
−
10"
9"
TOP VIEW
END VIEW
2 7/8"
5 1/2"
3/4"

INSTRUCTIONAL SUPPLEMENT #1

B. Make a storage board for components and wires, using the drawing as a guide. Drill holes 3/4 inch apart, measuring from center to center. (Figure B)

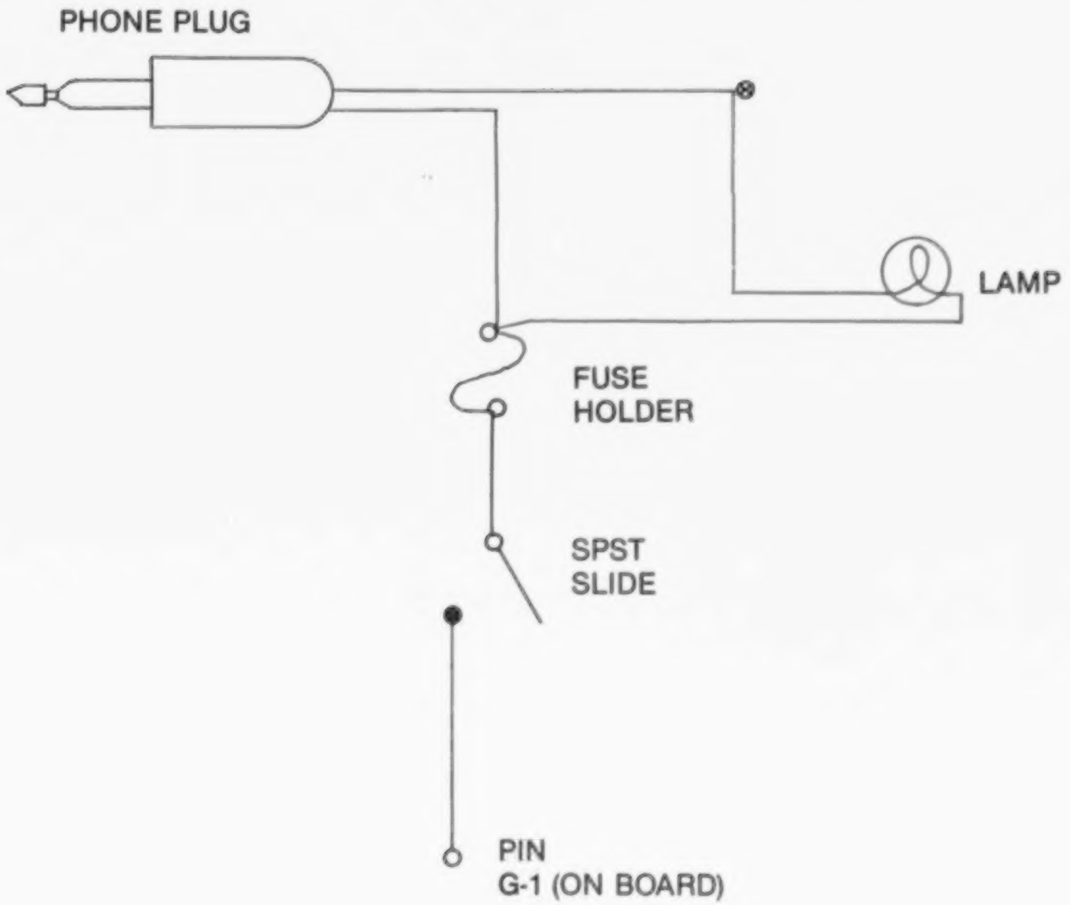
(NOTE: Storage board slides into rails inside box.)

FIGURE B



C. Extend 14 inches of wire from box to phone plug. (Figure C)

FIGURE C


PHONE PLUG
LAMP
FUSE HOLDER
SPST SLIDE
PIN G-1 (ON BOARD)

TECHNICAL INFORMATION SUPPLEMENT #1--Proper Connection of a Voltmeter

A. Determine the approximate voltage of the circuit

B. Select the proper AC or DC settting

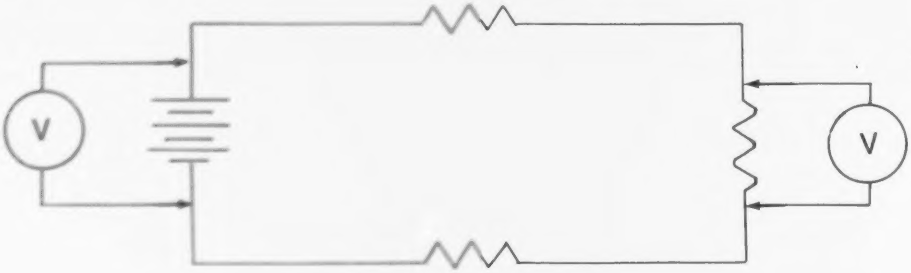
C. Select a scale that will be higher than the known circuit voltage

D. Turn circuit power ON

E. Connect the voltmeter in parallel (Figure 1)

(NOTE: As you connect the voltmeter, observe polarity. Black is negative; red is positive. If the voltmeter reads backwards, you have the wrong polarity and should reverse the leads. If the voltmeter pegs, you are on too low a scale and should switch to a higher scale.)

FIGURE 1



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TECHNICAL INFORMATION SUPPLEMENT #2--Proper Connection of an Ohmmeter

A. Select the proper resistance scale

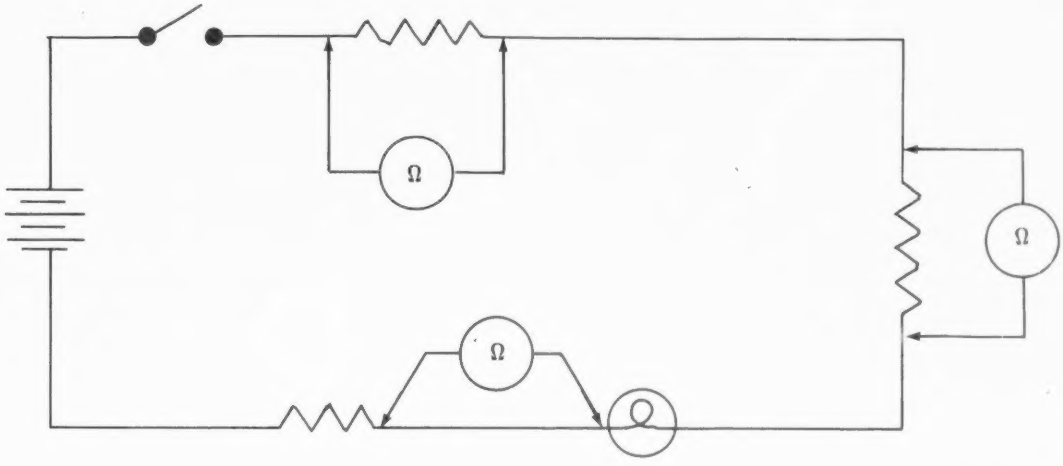
B. Zero the ohmmeter

C. Turn circuit power OFF

D. Connect the ohmmeter probes in series across resistance or wire to be checked (Figure 2)

(NOTE: The ohmmeter should read correct resistance [continuity] or zero.)

FIGURE 2



TECHNICAL INFORMATION SUPPLEMENT #3--Proper Connection of an Ammeter

A. Determine the approximate amperage of the circuit

B. Select the proper AC or DC setting

C. Select a scale that will be higher than the known circuit amperage

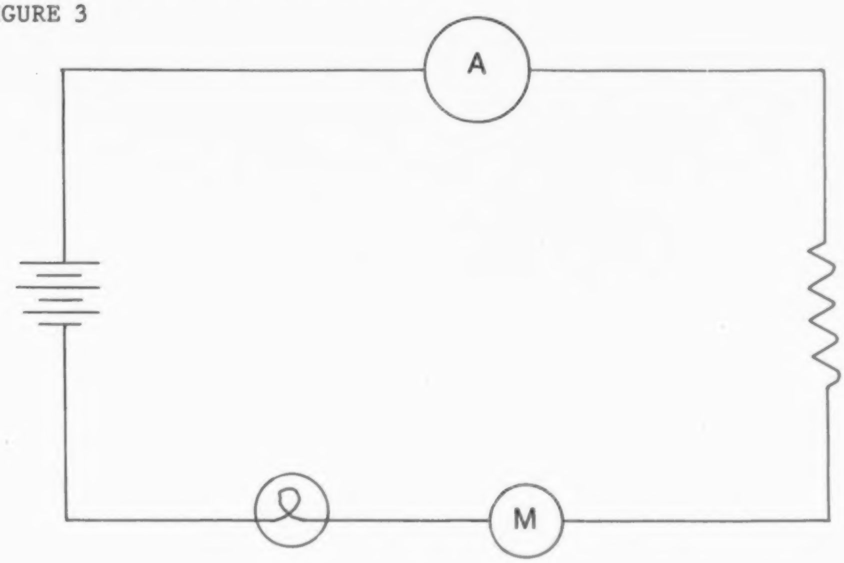
D. Turn circuit power OFF

E. Open the circuit at the point current is to be measured

F. Connect the ammeter in series (Figure 3)

(NOTE: As you connect the ammeter, observe polarity. Black is negative; red is positive. If the ammeter reads backwards, the polarity is wrong and you should reverse the leads.)

FIGURE 3



G. Turn circuit power ON

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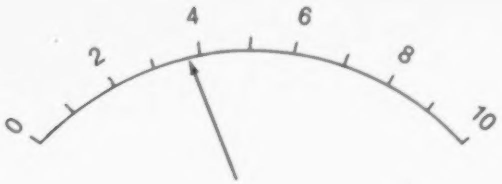
TECHNICAL INFORMATION SUPPLEMENT #4--Interpret the Scales of a Multimeter

The device used to indicate the operating conditions of a circuit is a meter. It consists of a magnetic field, a moving coil with pointer, and a graduated scale. This device is recognized by several names: VOM, volt-ohmmeter, volt-ohm-ammeter, and multimeter. The device has the ability to measure current, voltage, and ohms.

When the meter is correctly connected to the circuit, the magnetic field will cause a reaction that will drive the pointer up the scale. The circuit conditions determine the amount of pointer movement.

There are two types of scales found on the multimeter: the linear scale and the nonlinear scale. The linear scale consists of 10 equally spaced primary divisions with number readings of 0 to 10 (Figure 4).

FIGURE 4



The linear scale is further divided into 10 secondary divisions (Figure 5) and each secondary division is divided into tertiary divisions (See Figure 6).

FIGURE 5

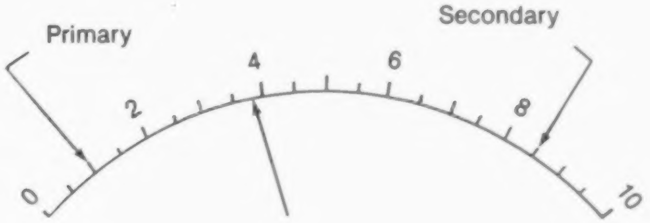
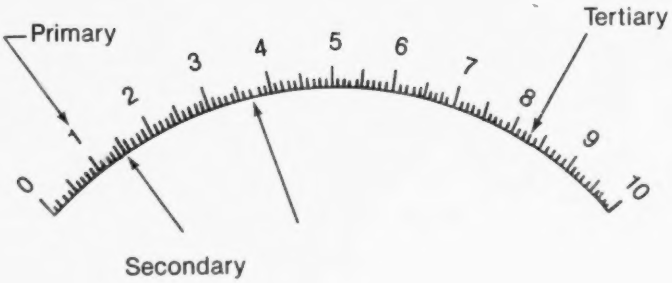


FIGURE 6


Primary
Tertiary
Secondary
0
1
2
3
4
5
6
7
8
9
10

To read the multimeter, look at the position of the pointer on the scale. Figure 7 indicates a reading of 7.8; Figure 8, a reading of 8.0; and Figure 9 indicates a reading of 2.4.

FIGURE 7

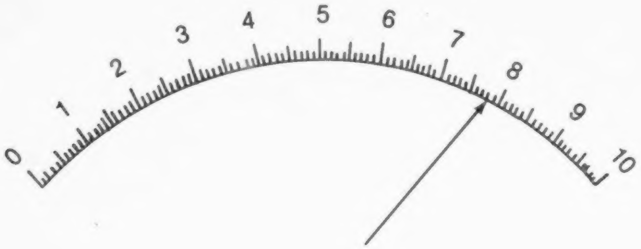

0
1
2
3
4
5
6
7
8
9
10

FIGURE 8

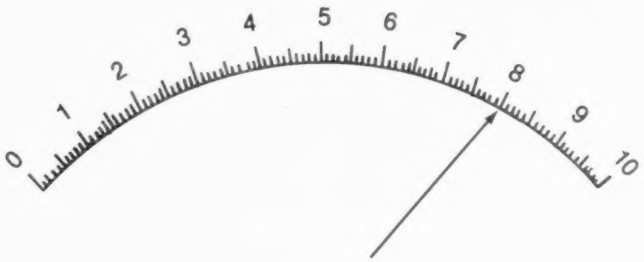
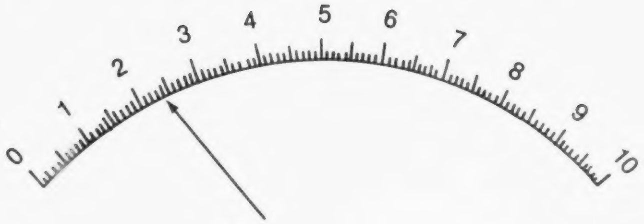
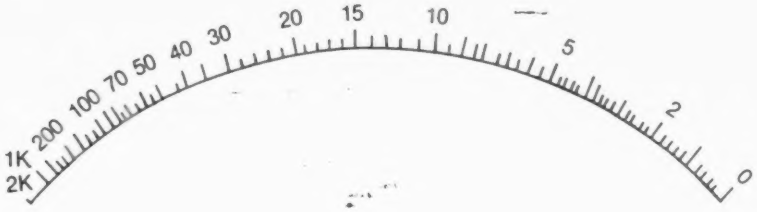

0
1
2
3
4
5
6
7
8
9
10

FIGURE 9


0
1
2
3
4
5
6
7
8
9
10

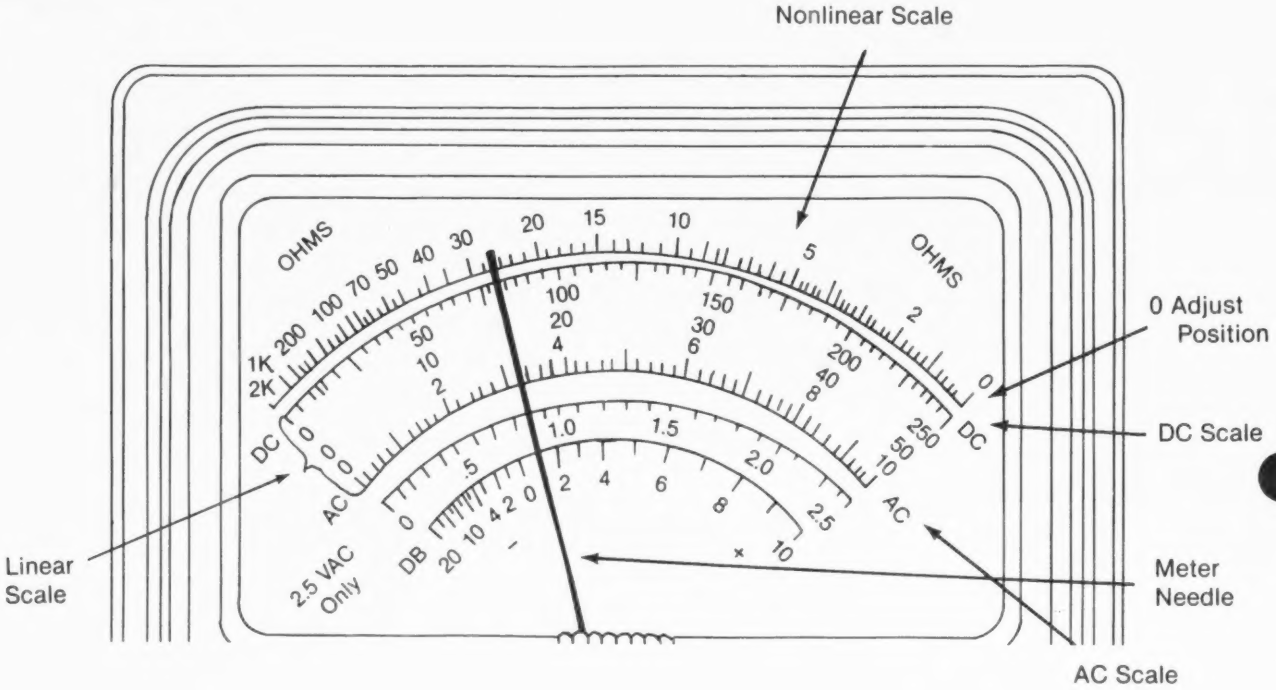
The nonlinear scale is read in the same way as a linear scale. However, the scale numbers range from 200 to 0. As the scale numbers increase, the primary divisions of the nonlinear scale become smaller (Figure 10).

FIGURE 10


2K
1K
200
100
70
50
40
30
20
15
10
5
2
0

A multimeter will have at least one nonlinear scale and several linear scales. One scale will usually serve as the scale for both AC and DC readings. The scale's purpose will be indicated by a symbol or abbreviation found at the end of the scale (Figure 11 and Transparency Master #1).

FIGURE 11


Nonlinear Scale
0 Adjust Position
DC Scale
Linear Scale
Meter Needle
AC Scale
OHMS
OHMS
1K 2K 200 100 70 50 40 30 20 15 10 5 2 0
DC
AC
0 0 0
50 10 2
100 20 4
150 30 6
200 40 8
250 50 10
DC
AC
0 .5 1.0 1.5 2.0 2.5
DB 20 10 4 2 0 2 4 6 8 10
2.5 VAC Only

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TECHNICAL INFORMATION SUPPLEMENT #5--The Digital Multimeter

(NOTE: This technical information supplement was written from the FLUKE 75 and 77 Multimeter Operations Manual. If you are using a different brand multimeter, be sure to check the operations manual before proceeding.)

I. Safety symbols

A. ⚠ - Indicates the operator must refer to an explanation in the operator's manual.

B. ϟ - Indicates terminals at which dangerous voltages may exist

C. ∿ - AC rms

D. ⎓ - DC

E. -▭- - Fuse

F. ⧈ - Protection Class II

II. Safety precautions

A. Use meter only in circuits limited by fuse or circuit breaker to 20A or 4000 VA

B. Do not apply more than 1000V DC or 1000V AC between any terminal and earth ground

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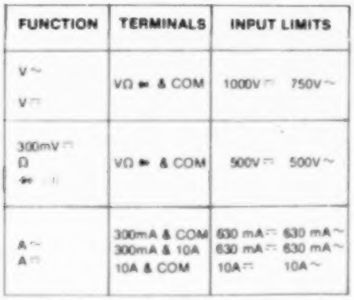
C. Do not exceed the following input limits (Figure 12)

FIGURE 12



FUNCTION	TERMINALS	INPUT LIMITS
V ~ V ⎓	VΩ ▶| & COM	1000V ⎓ 750V ~
300mV ⎓ Ω ▶| ·)))	VΩ ▶| & COM	500V ⎓ 500V ~
A ~ A ⎓	300mA & COM 300mA & 10A 10A & COM	630 mA ⎓ 630 mA ~ 630 mA ⎓ 630 mA ~ 10A ⎓ 10A ~

D. To avoid electrical shock when working above 60V DC or 25V AC rms, be sure test leads are in good condition

E. When working above 500V, disconnect test leads from test points before changing functions

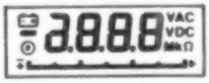
F. Clean case with damp cloth and mild detergent; do not use abrasives or solvents

III. Operating instructions

(NOTE: For correct readings in ohms or →| ·))) , ensure power is off in devices being tested. Environments with rf noise or arcing may cause improper display of symbols.)

A. Power-up self-test - When meter is turned on, all display segments appear (Figure 13) while the instrument performs a brief self-test. At the end of the test, the meter chirps once and begins taking readings

FIGURE 13



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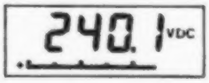
B. Readings - The digital display is updated 2 1/2 times per second. The analog display gives a graphic indication of the input level; it is updated 25 times per second, and has separate polarity indicators (Figure 14)

FIGURE 14



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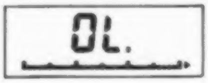
C. Overload indication - These symbols indicate the input is too large to display. The location of the decimal point depends on the measurement range (Figure 15)

FIGURE 15



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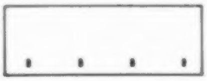
D. Standby - To extend battery life, the display blanks after one hour if the meter is not being used. To resume operation, turn the rotary switch (Figure 16)

FIGURE 16



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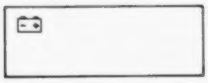
E. Low battery indicator - This symbol appears when approximately 100 hours of battery life remains. For proper operation, replace the battery as soon as possible (Figure 17)

FIGURE 17



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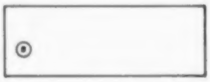
F. Range hold and touch hold - This symbol indicates that either the range hold or touch hold is activated (Figure 18)

FIGURE 18



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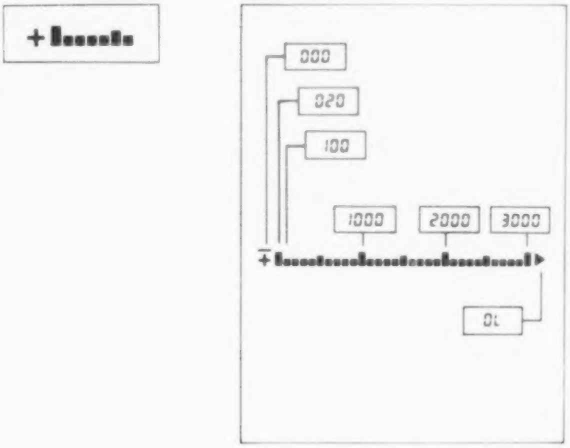
G. Analog display - The analog display is especially helpful for peaking and nulling and for observing rapidly changing inputs. The bar indicates the magnitude of the input compared to the full scale value of the measurement range in use. In V ⎓, 300 mV ⎓, and A ⎓ , a + or - indicates the polarity of the input. In all other functions, the + or - disappears, but the - still appears near zero (Figure 19)

FIGURE 19



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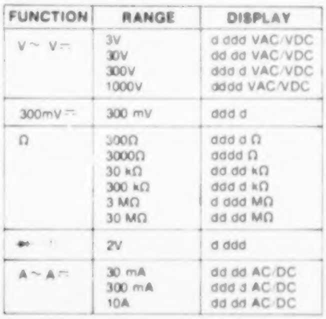
H. Autorange - The meter powers up in autorange. In autorange, the meter automatically selects the measurement range that gives the best resolution. The display indicates OL while the meter goes to a higher range, and blanks while the meter goes to a lower range. The range can be interpreted from the display as shown in the following table (Figure 20)

FIGURE 20



FUNCTION	RANGE	DISPLAY
V ~ V ⎓	3V	d ddd VAC/VDC
	30V	dd dd VAC/VDC
	300V	ddd d VAC/VDC
	1000V	dddd VAC/VDC
300mV ⎓	300 mV	ddd d
Ω	300Ω	ddd d Ω
	3000Ω	dddd Ω
	30 kΩ	dd dd kΩ
	300 kΩ	ddd d kΩ
	3 MΩ	d ddd MΩ
	30 MΩ	dd dd MΩ
▶|	2V	d ddd
A ~ A ⎓	30 mA	dd dd AC/DC
	300 mA	ddd d AC/DC
	10A	dd dd AC/DC

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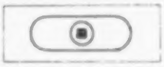
I. Range hold - Range hold lets you select a fixed measurement range. The display will indicate OL if a measurement is too large to display in selected range (Figure 21)

FIGURE 21



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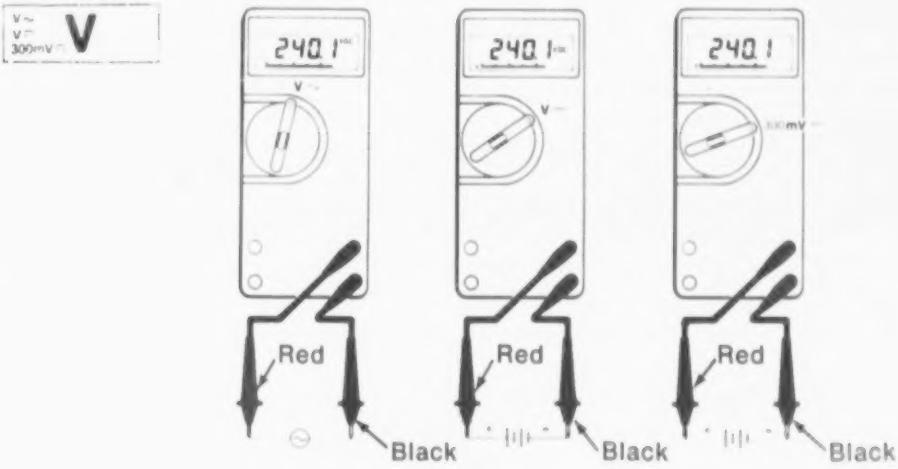
J. Touch hold - The meter will capture a reading when the test leads touch a circuit or when the range button is pressed. This lets you lift the test leads before reading the display

K. Voltage measurement - Select the VAC or VDC function (V~ or V⎓) and connect the test leads as shown in the illustrations below. Select the 300mV ⎓ function for best resolution below 320 mV DC. In the 300 mV ⎓ function, readings are displayed in mV and the VDC symbol blanks (Figure 22)

FIGURE 22



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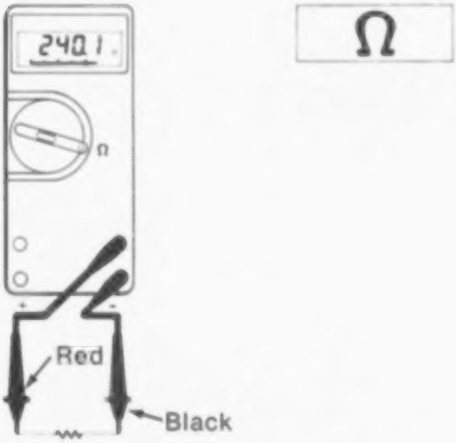
L. Resistance measurement - Disconnect the test leads as shown in the following illustration. Units are indicated by Ω , KΩ , or MΩ in the display. For correct readings, ensure that the device being tested contains no voltage. No readings may result if voltage is present (Figure 23)

FIGURE 23



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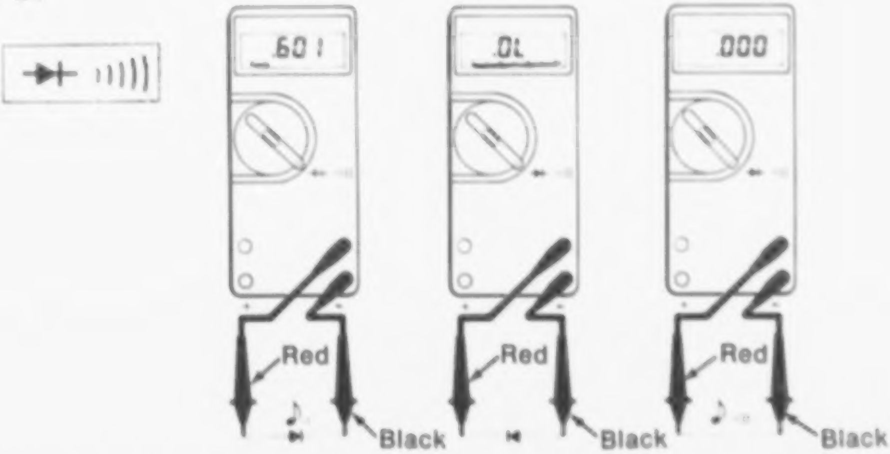
M. Diode test (Figure 24)

1. Forward bias - The meter displays the forward voltage drop (V_F) in volts up to 2V., and beeps briefly for one diode drop (V_f <0.7V).

2. Reverse bias or open circuit - The meter displays OL

3. Short circuit - The meter emits a continuous tone

FIGURE 24



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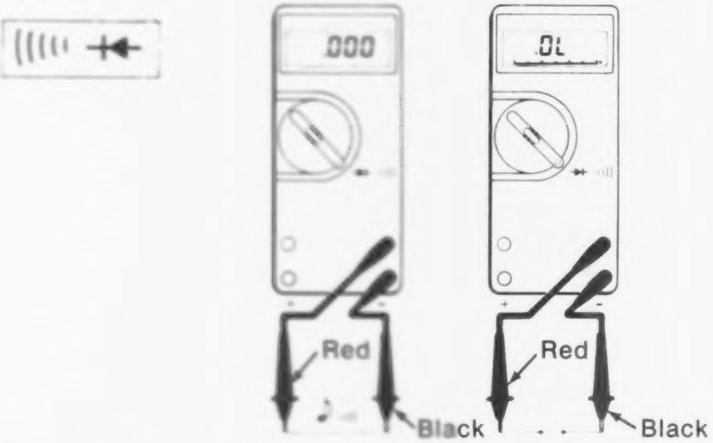
N. Continuity beeper - A continuous tone sounds if the resistance between the terminals is less than approximately 150 (100 counts in display.) The display indicates the approximate test voltage across the terminals (Figure 25)

FIGURE 25



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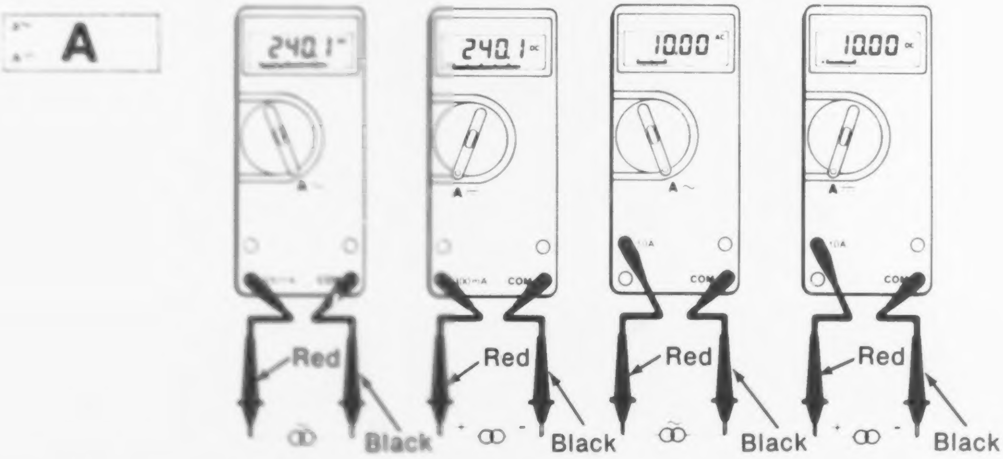
O. Current measurement - Select the AC or DC function (A~ or A⎓). For measurements up to 320 mA, connect the test leads to the 300 mA and COM terminals, or alternatively, to the 300 mA and 10A terminals. The 300 mA terminal is limited to 630 mA by two protective fuses. If a fuse blows, the meter will display approximately zero. For measurements up to 10A, use the 10A and COM terminals. The 10A and COM terminals may also be used for measurements between 10A and 20A for up to 30 seconds (Figure 26)

FIGURE 26



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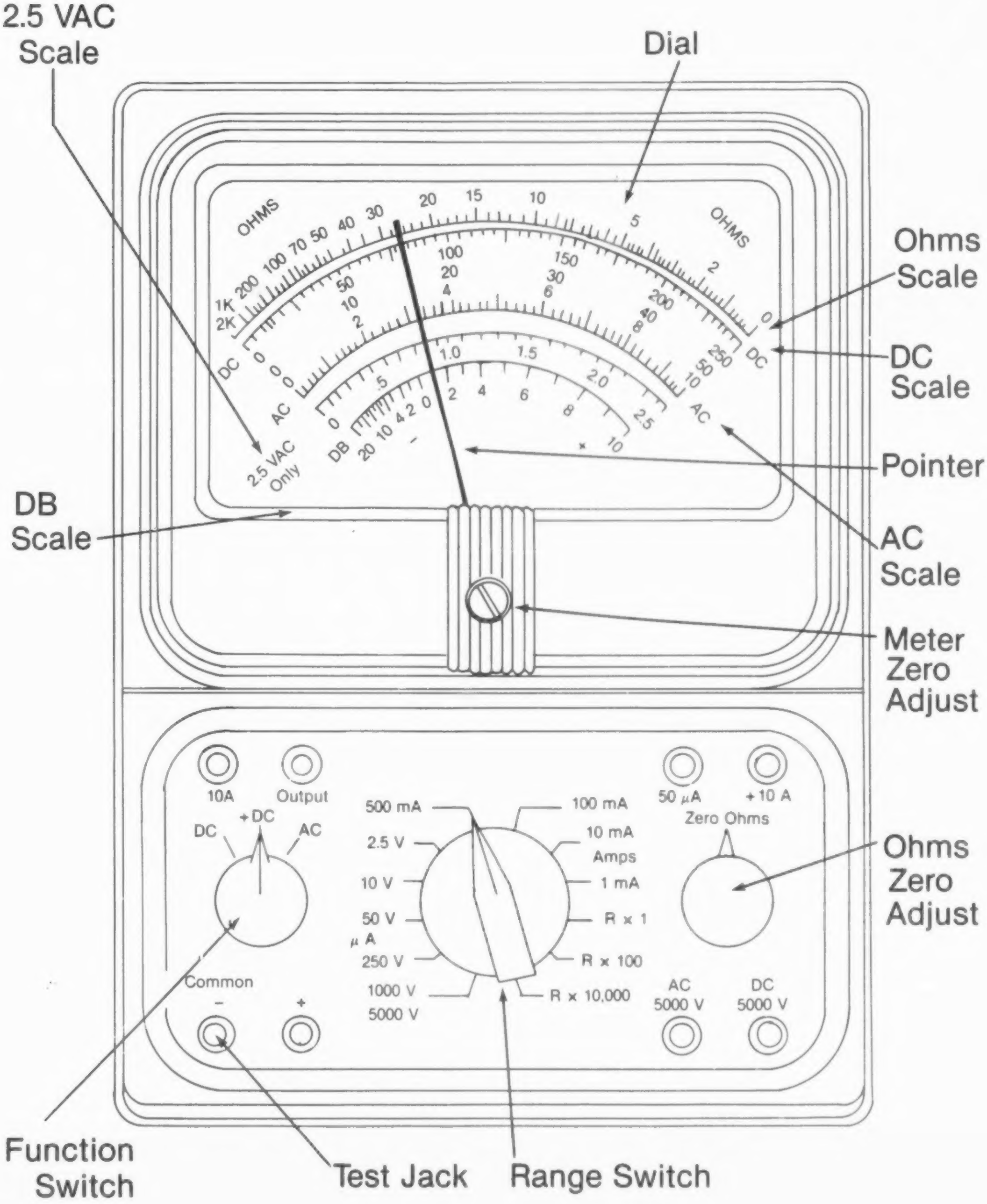
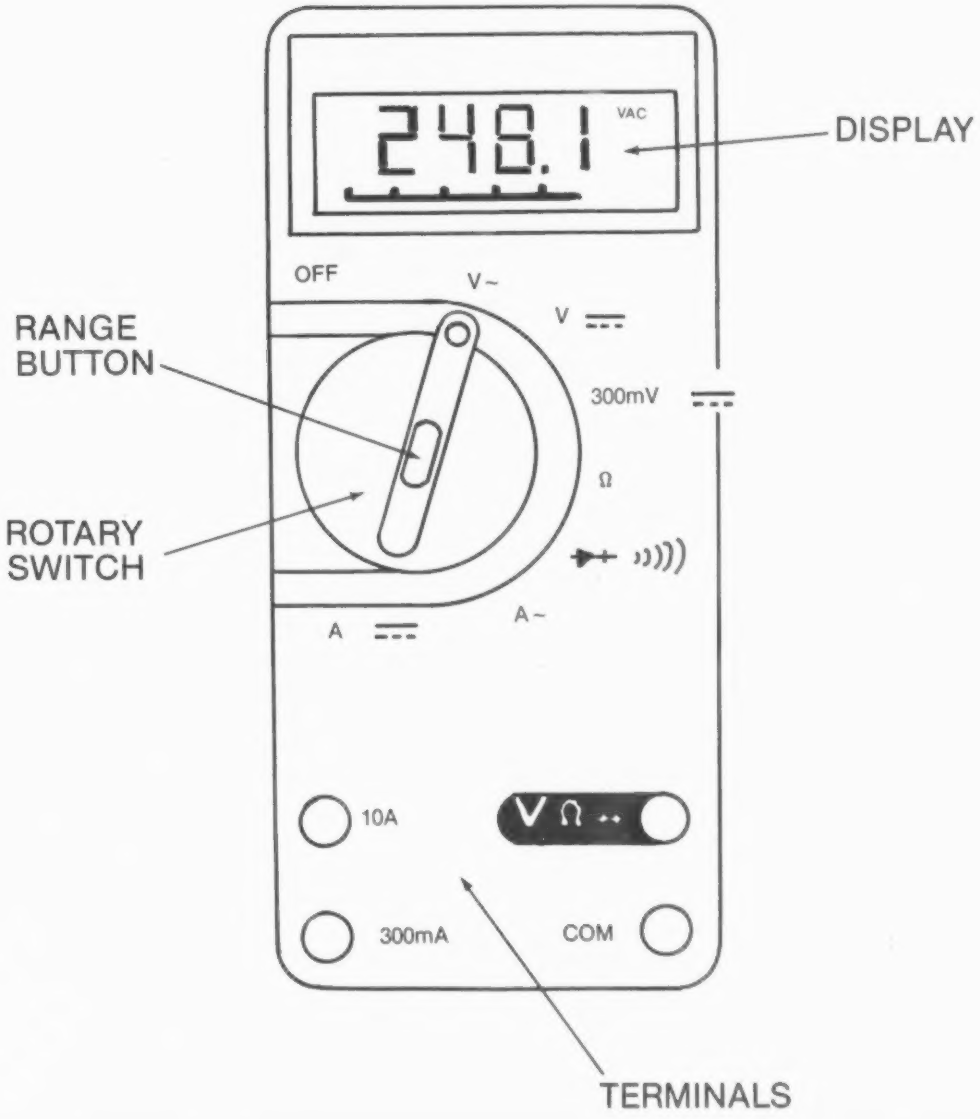
Parts of a Multimeter


2.5 VAC Scale
Dial
Ohms Scale
DC Scale
Pointer
AC Scale
DB Scale
Meter Zero Adjust
Ohms Zero Adjust
Function Switch
Test Jack
Range Switch
OHMS
OHMS
DC
AC
2.5 VAC Only
DB
10A
Output
DC
+DC
AC
Common
500 mA
2.5 V
10 V
50 V
µA
250 V
1000 V
5000 V
100 mA
10 mA
Amps
1 mA
R × 1
R × 100
R × 10,000
50 µA
+10 A
Zero Ohms
AC 5000 V
DC 5000 V

Parts of A Digital Multimeter


248.1
VAC
DISPLAY
OFF
V~
V ⎓
300mV ⎓
RANGE BUTTON
ROTARY SWITCH
Ω
A ⎓
A~
10A
V Ω
300mA
COM
TERMINALS

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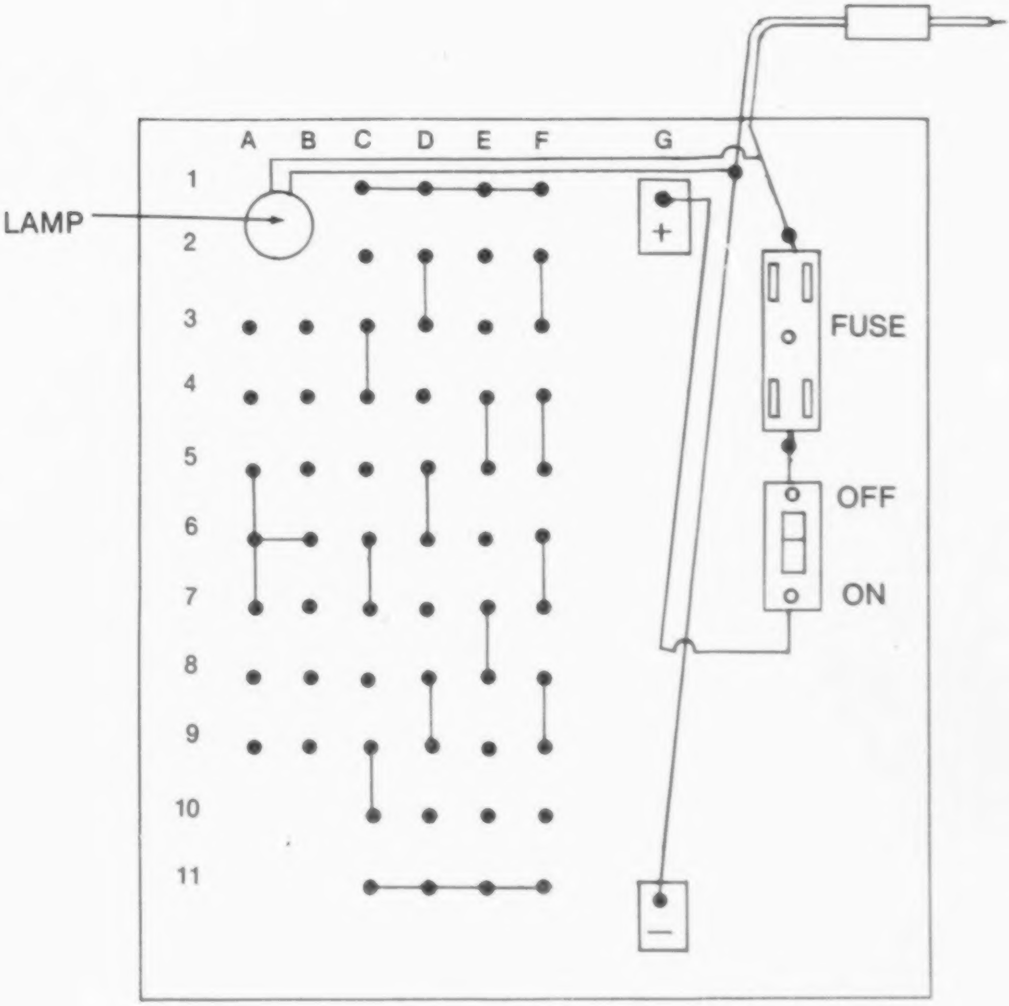
Example of a Project Board (Breadboard)


A
B
C
D
E
F
G
1
2
3
4
5
6
7
8
9
10
11
LAMP
+
FUSE
OFF
ON
—

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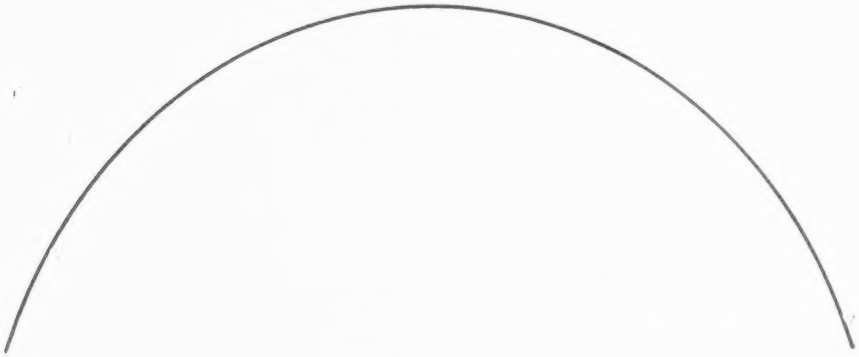
WORKBOOK SUPPLEMENT #1--Read the Multimeter

This exercise will help you become familiar with meter functions and scales.

A. In the space provided below, draw the scales of your meter and insert all numbers and letters pertaining to the scale.



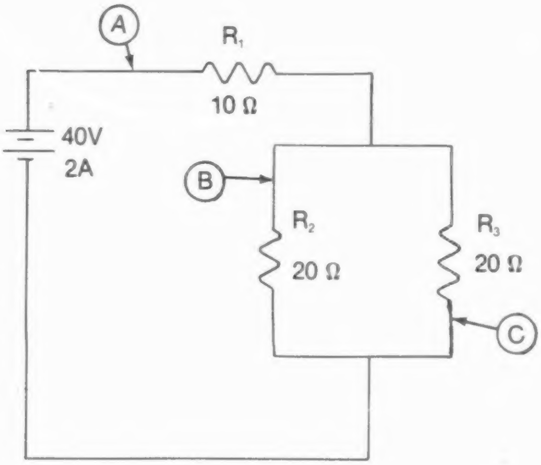
B. Label the meter function (DC volts, AC volts, DC amps) and resistance for which each scale below is used on the meter face above

1. Center scale reading on R x 1 ____________________
2. AC voltage ranges ____________________
3. Ohms/volt direct current ____________________
4. Ohms/volt alternating current ____________________
5. DC voltage ranges ____________________
6. DC current ranges ____________________
7. Resistance ranges ____________________

WORKBOOK SUPPLEMENT #2--Analyze an Electrical Circuit Diagram Showing Multimeter Connections

It is necessary to understand how to insert the meter into the circuit properly to analyze circuit operation. The following problems will allow you to further develop your competency in analyzing electrical circuits. Answer the following questions.

A. Fill in the missing values



$E_T = 40$ V
$I_T = 2$ A
$R_T =$ ____
$E_1 =$ ____
$I_1 =$ ____
$R_1 = 10\ \Omega$

$E_2 =$ ____
$I_2 =$ ____
$R_2 = 20\ \Omega$
$E_3 =$ ____
$I_3 =$ ____
$R_3 = 20\ \Omega$

B. If an open occurred at point A, what would happen to I_T? ____________

C. If an open occurred at point B, what would happen to

1. I_3? ____________
2. R_T? ____________

D. If a short occurred at Point C, what would happen to

1. I_T? ________________________________

2. R_T? ________________________________

E. Match Ohm's law and Kirchhoff's laws to their correct definitions. Write the correct letters in the blanks.

____1. The algebraic sum of the voltage and the voltage drop around any closed circuit is equal to zero

____2. Current is equal to voltage divided by resistance

____3. The algebraic sum of the currents at any junction of conductors is zero

a. Ohm's law

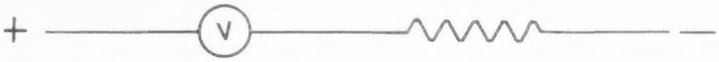
b. Kirchhoff's voltage law

c. Kirchhoff's current law

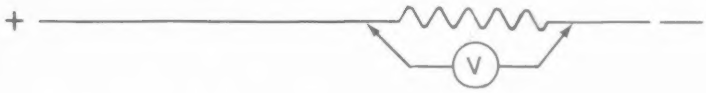
F. How many of the above laws were used in the circuit? ____________

G. Which voltmeter is hooked up properly? (1 or 2) ______________

1.

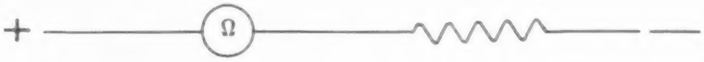


2.

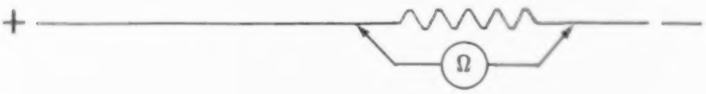


H. Which ohmmeter is hooked up properly (1 or 2) ________________

1.

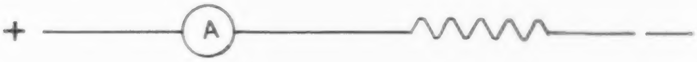


2.

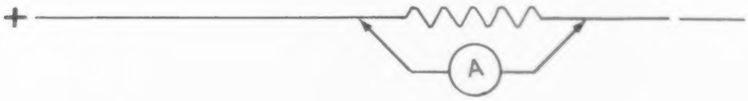


I. Which ammeter is hooked up properly? (1 or 2) ______________________

1.



2.



J. Select true statements related to analyzing an electrical circuit. Circle the number before each correct response.

1. Power must be ON to check voltage.

2. Power must be ON to check current.

3. Power must be ON to check resistance.

4. Power must be ON to check continuity.

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ANSWERS TO WORKBOOK SUPPLEMENTS

WORKBOOK SUPPLEMENT #1 - Evaluated to the satisfaction of the instructor

WORKBOOK SUPPLEMENT #2

A. $R_T = 20\Omega$

$E_1 = 20$ V
$I_1 = 2$ A

$E_2 = 20$ V
$I_2 = 1$ A

$E_3 = 20$ V
$I_3 = 1$ A

B. It would go to zero

C. 1. I_3 would increase to 2 A
2. R_T would increase to 30Ω

D. 1. I_T would increase to 4 A
2. R_T would decrease to 10Ω

E. 1. b
2. a
3. c

F. All three

G. 2

H. 2

I. 1

J. 1, 2

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MEASURE VOLTAGE, CURRENT, RESISTANCE, AND CONTINUITY
G105-C

PROJECT GUIDE #1--Construct a Circuit From a Schematic Diagram

PURPOSE: To give you A & P training and experience needed to construct circuits from schematic diagrams.

EQUIPMENT AND TOOLS NEEDED:

A. Project board

B. Project board components

SUPPLIES AND MATERIALS:

A. Resistors

1. R_1 - 47Ω
2. R_2 - 560Ω
3. R_3 - 1100Ω
4. R_4 - 4700Ω
5. R_5 - 3300Ω
6. R_6 - 1000Ω
7. R_7 - 1000Ω
8. R_8 - 1500Ω
9. R_9 - 1100Ω
10. R_{10} - 470Ω
11. R_{11} - 10,000Ω
12. R_{12} - 390Ω

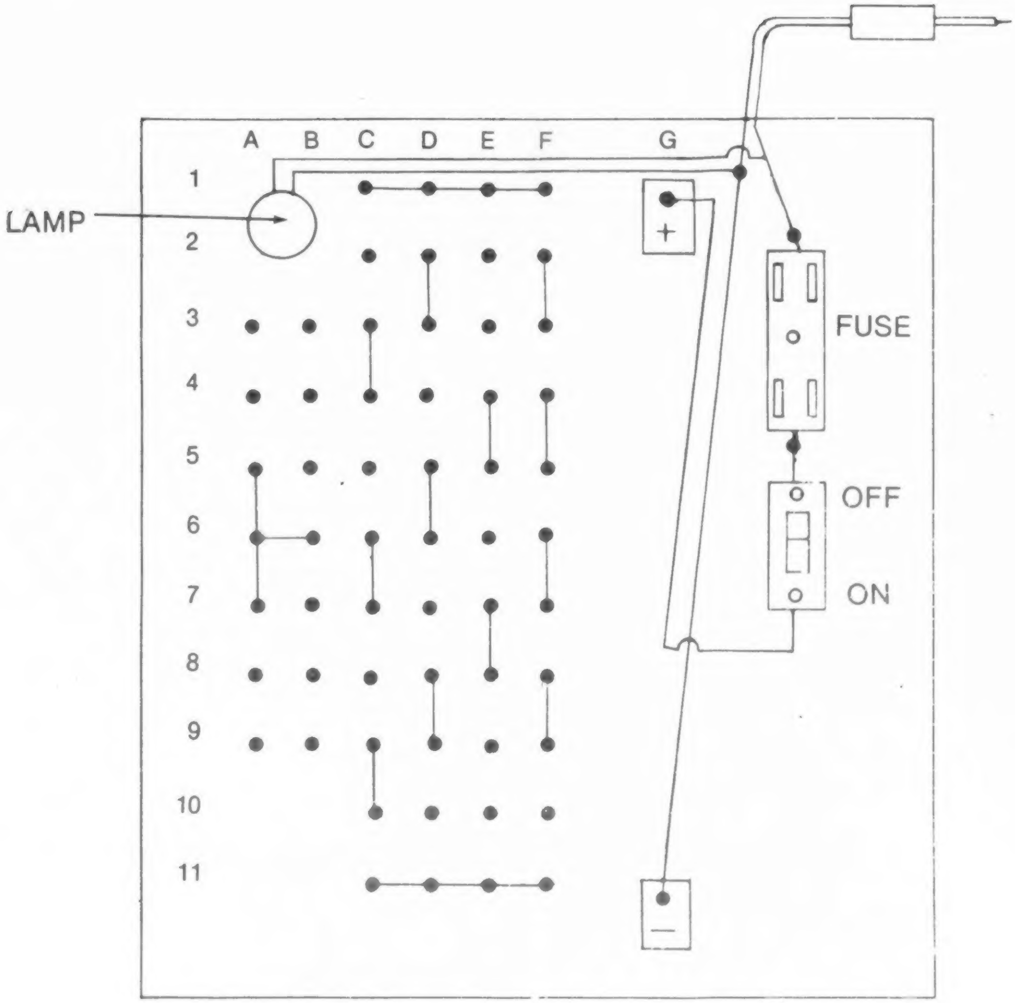
B. 2 black lead wires

C. 2 red lead wires

PROCEDURE:

Every connection on the project board has a coordinate location: rows #1 through #11 and columns A through G. The electrical ground is in the lower right hand corner (See Figure 27 on next page)

FIGURE 27


A
B
C
D
E
F
G
1
2
3
4
5
6
7
8
9
10
11
LAMP
+
FUSE
OFF
ON
—

PROJECT GUIDE #1

A. Turn power OFF

B. Install the following components on the project board at the correct coordinates

(NOTE: This project is designed to practice installing various components and will not be used to measure any electrical values.)

1. Install R_1 at C_1 and C_2
2. Install R_2 at D_1 and D_2
3. Install R_3 at E_1 and E_2
4. Install R_4 at F_1 and F_2
5. Install R_5 at A_3 and B_3
6. Install R_6 at A_4 and B_4
7. Install R_7 at A_5 and B_5
8. Install R_8 at A_6 and B_6
9. Install R_9 at A_7 and B_7
10. Install R_{10} at A_8 and B_8
11. Install R_{11} at A_9 and B_9
12. Install R_{12} at C_3 and D_3
13. Install red lead wire at C_{10} and C_{11}
14. Install red lead wire at D_{10} and D_{11}
15. Install black lead wire at E_{10} and E_{11}
16. Install black lead wire at F_{10} and F_{11}

(NOTE: The instructor will inspect the completed project board and advise you if changes are required.)

C. After instructor has checked your work, remove all components

PROJECT GUIDE #2--Determine Continuity of a Circuit

PURPOSE: In troubleshooting a circuit, there are three possible problems: (a) open (b) short (c) cross-short. We can eliminate the possiblity of an open by checking the continuity. A continuity check determines whether you have a complete circuit. This project guide will allow you to develop competency in measuring the continuity of a circuit.

EQUIPMENT AND TOOLS NEEDED:

A. Student multimeter

B. Project board

C. Project board components

SUPPLIES AND MATERIALS:

A. Wire of the following colors; one end collared and the other end non-collared on each wire

1. Black
2. Brown
3. Red
4. Orange
5. Yellow
6. Green
7. Blue
8. Violet
9. Gray
10. White

PROCEDURE:

A. Set ohmmeter to R x 1 scale

B. Zero the ohmmeter

C. Complete the chart on the next page, using the ohmmeter and continuity cables

   1. Check each wire for continuity - color to color. Record either open or continuity

   2. Check each wire on collared end with every wire on the non-collared end and record either open or short for each wire

3. Check each wire on the non-collared end and record either open or short for each wire

Collared End	Open	Short	Continuity	Non-Collared End
Black				Black
Brown				Brown
Red				Red
Orange				Orange
Yellow				Yellow
Green				Green
Blue				Blue
Violet				Violet
Gray				Gray
White				White

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PROJECT GUIDE #3--Analyze Resistors in a Circuit

PURPOSE: The resistance of various resistors can be determined by using the color code markings and by using the ohmmeter function of the VOM to measure resistance. Resistor tolerance can then be calculated using the values obtained. This project guide will allow you to develop competency in analyzing resistors in a circuit.

EQUIPMENT AND TOOLS NEEDED:

A. Student multimeter

B. Project board

C. Project board components

SUPPLIES AND MATERIALS:

A. Resistors

1. R_1 - 47 Ω

2. R_2 - 560 Ω

3. R_3 - 1100 Ω

4. R_4 - 4700 Ω

5. R_5 - 33,000 Ω

PROCEDURE:

A. Fill in the chart on the next page for each of the designated resistors, using the step-by-step procedure listed below

1. Fill in first four lines by reading the color bands on the individual resistors

2. Fill in line #5 by using line #4 color code

3. Using ohmmeter, measure resistance; record on line #6

4. Calculate the tolerance of each resistance by subtracting line #6 from Line #0, dividing the difference by line #0, and multiplying by 100%

PROJECT GUIDE #3

Step 1	Step 2	Step 3
Determine the difference	Divide the difference by coded value	Multiply times 100%

EXAMPLE:

470 (coded value)
-465 (measured value)
5 ohms--------------$470\overline{)\,5.000}$ X 100% = 1% tolerance

		R_1	R_2	R_3	R_4	R_5
0	Coded Values, Ohms	470	560	1100	4700	33,000
1	First Color Band					
2	Second Color Band					
3	Third Color Band					
4	Fourth Color Band					
5	Coded Tolerance					
6	Measured Value, Ohms					
7	Calc. Tolerance					

PROJECT GUIDE #4--Measure Direct Current Voltage

PURPOSE: Voltage is electrical pressure that causes electrons to move along a conductor. A voltage scale of a multimeter is used to measure the difference in pressure between two points in a circuit. This project guide will allow you to develop competency in measuring DC current voltage and to develop competency using the voltage scale on the multimeter.

EQUIPMENT AND TOOLS NEEDED:

A. Student multimeter

B. Project board

C. Project board components

SUPPLIES AND MATERIALS:

A. Resistors

1. R_1 - 1000 Ω

2. R_2 - 1500 Ω

3. R_3 - 1500 Ω

4. R_4 - 4600 Ω

B. Black lead wire for jumpers

C. Red lead wire for jumpers

PROCEDURE:

In this project you will build a circuit on the project board, using resistors R_1 through R_4.

A. Make sure multimeter power is OFF before proceeding

B. Connect red jumper from G_1 to F_1

C. Place the resistors as follows:

  1. Install R_1 at D_1 and D_2
  2. Install R_2 at A_4 and B_4
  3. Install R_3 at C_7 and D_7
  4. Install R_4 at D_{10} and D_{11}

D. Connect black jumpers as follows:

  1. From D_2 to A_4
  2. From B_4 to C_7
  3. From D_7 to D_{10}
  4. From F_{11} to G_{11}

E. After completion of the circuit board layout, make a schematic diagram of the circuit

F. Turn power ON

G. Measure the voltage between G_1 and G_{11}. Record meter reading in the blank

(NOTE: Observe polarity and voltage scale before inserting meter.)

E_T = ______________________

H. Measure the voltage across each of the resistors. Record meter readings in the blanks

1. E_1 = ________ 3. E_3 = ________

2. E_2 = ________ 4. E_4 = ________

I. 1. How does the voltage in question G compare to the voltages in question H? ______________________________________

____

2. Do these voltages conform to Kirchhoff's laws? __________

____

3. How is the voltmeter connected in the circuit? __________

____

____

PROJECT GUIDE #5--Measure Direct Current

PURPOSE: Current flow in a circuit is dependent on the voltage and the resistance of the conductor. The ammeter portion of the multimeter is used to measure current flow in a circuit and is hooked in series with the device you wish to measure. This project guide will allow you to learn to measure direct current and read the current scale on the multimeter.

EQUIPMENT AND TOOLS NEEDED:

A. Student multimeter

B. Project board

C. Project board components

SUPPLIES AND MATERIALS:

A. Resistors

1. R_1 - 47 Ω
2. R_2 - 1100 Ω
3. R_3 - 1100 Ω
4. R_4 - 470 Ω

B. Red lead wire for jumpers

C. Black lead wire for jumper

PROCEDURE:

In this project you will build a circuit on the project board and will use that circuit to make various calculations to determine current flow.

A. Make sure power is OFF

B. Build your circuit as follows:

1. Install R_1 at D_1 and D_2
2. Install R_2 at A_5 and B_5

3. Install R_3 at B_6 and C_6

4. Install R_4 at C_{10} and C_{11}

C. Connect red jumpers as follows:

1. From D_2 to B_5

2. From D_3 to C_6

3. From A_7 to C_9

D. Connect black jumper from F_{11} to G_{11}

E. Complete the circuit by installing meter between F_1 and G_1

(NOTE: Observe polarity and be sure meter is in series.)

F. Turn power ON and record current total

I_T = ____________________ milliamperes

G. Turn power OFF and remove meter from circuit

H. Remove red jumper from between D_2 to B_5 and replace at G_1 and F_1

I. Complete the circuit by installing the meter between D_2 and B_5

(NOTE: Observe polarity and be sure meter is in series.)

J. Turn power ON and record reading

I_2 = ____________________________ milliamperes

K. Turn power OFF and remove meter from circuit

L. Remove red jumper from between D_3 and C_6 and replace at D_2 and B_5

M. Complete the circuit by installing meter between D_3 and C_6

(NOTE: Observe polarity and series.)

1. With which resistor is the meter in series now? ____________

____

2. Turn power ON and record reading

I_3 = ___________________________ milliamperes

N. Turn power OFF and remove meter from circuit

O. Remove jumper between A_7 and C_9 and replace at D_3 and C_6

P. Install meter between A_7 and C_9

(NOTE: Observe polarity and series.)

Q. Turn power ON and record reading

1. I_4 = ____________________ milliamperes
2. What previous reading is this equal to? ____________________

   ____

   ____
3. Why? ____

   ____
4. Does $I_2 + I_3 = I_4$? ________________________________
5. Why or why not? ____

   ____

R. In the space below, make a schematic drawing of the completed circuit showing the current flow of each component

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PROJECT GUIDE #6--Perform Circuit Analysis Using Ohm's Law

PURPOSE: Electrical circuits can be analyzed by using Ohm's law to calculate the resistance of each of the circuits and the resistors that make up a circuit. By using a multimeter and the Ohm's law formula, you can determine a great deal of information. This project guide will allow you to develop competency in circuit analysis using Ohm's law.

EQUIPMENT AND TOOLS NEEDED:

A. Student multimeter

B. Project board

C. Project board components

SUPPLIES AND MATERIALS:

A. Resistors

1. R_1 - 1100 Ω , 1 watt
2. R_2 - 10,000 Ω , 1 watt
3. R_3 - 4700 Ω , 1 watt

PROCEDURE:

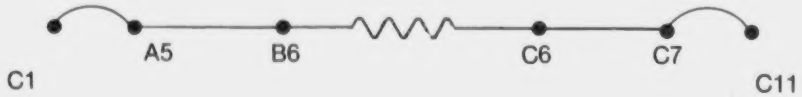
A. Complete the chart on the following page

1. Measure and record the actual values of R_1, R_2, and R_3
2. Record the resistance as color-coded for R_1, R_2, and R_3
3. Record the color codes of R_1, R_2, and R_3
4. Calculate and record the resistance tolerance of R_1, R_2, and R_3

PROJECT GUIDE #6

	Resistance As Measured	Resistance As Color-Coded	Color Code	Resistor Tolerance
R_1				
R_2				
R_3				

B. Set up the circuit shown below on the project board. Use coordinates indicated



C. Complete the above circuit by installing ammeter between F_1 and G_1

(NOTE: Observe polarity and be sure ammeter is installed in series.)

D. Turn power ON and record current reading

I_T - ________________________ milliamperes

E. Using Ohm's law, when current and resistance are known, calculate the voltage (E). Record below

E = ____

F. Turn power OFF and remove ammeter from circuit

G. Reconnect lead from C_1 to G_1

H. Turn power ON

I. Read voltage between E_1 and G_{11}. Record the reading below

1. ________________________ voltage

2. To what voltage does this compare? ____________________________

____

3. Is it equal to the voltage in step E? ____________________

   ____

4. Should it be? ____

J. Turn power OFF

K. Replace R_1 with R_2 and repeat steps B through I. Answer the following questions:

1. ______________________ voltage

2. To what voltage does this compare? ____________________

   ____

3. Is it equal to the voltage in step E? ____________________

   ____

4. Should it be? ____

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PROJECT GUIDE #7--Perform Series Circuit Analysis Using Electrical Measuring Devices

PURPOSE: Series circuits can be analyzed for voltage, resistance, and current flow by using a multimeter. This information can be used to make critical observations relevant to the circuit's characteristics. This project guide will allow you to develop competency in performing series circuit analysis using electrical measuring devices.

EQUIPMENT AND TOOLS NEEDED:

A. Student multimeter

B. Project board

C. Project board components

SUPPLIES AND MATERIALS:

A. Resistors

1. R_1 - 47Ω, 1 watt
2. R_2 - 560Ω, 1 watt
3. R_3 - 47Ω, 1 watt
4. R_4 - 1100Ω, 1 watt

B. Red lead wire

PROCEDURE:

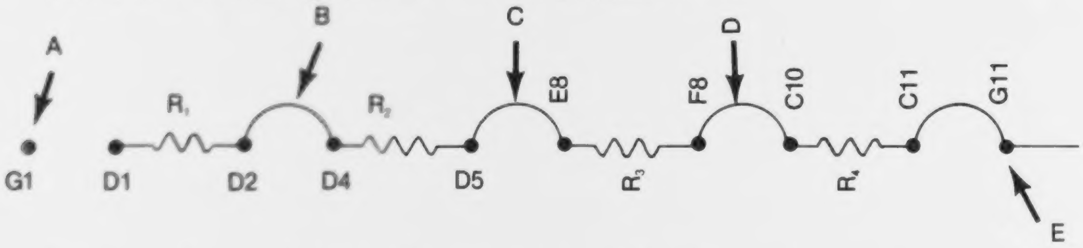
A. Complete the following table

(NOTE: This information will be used in future calculations.)

	Color Code	Color-Coded Resistance	Measured Resistance	Calculated % of Tolerance
R_1				
R_2				
R_3				
R_4				

PROJECT GUIDE #7

B. Build the following circuit on the project board



C. Measure the resistance between the following points. Record the resistance in the blanks.

1. D_1 and C = ________________________

2. D_1 and D = ________________________

3. D_1 and E = ________________________

D. Place red lead between D_1 and G_1

E. Turn power ON and measure voltage drop across each resistor. Record the reading in the blanks.

1. E_{R_1} ________________________

2. E_{R_2} ________________________

3. E_{R_3} ________________________

4. E_{R_4} ________________________

F. Add all voltage drops in step E. Use Kirchhoff's voltage law to compute total voltage. Record the total voltage in the blank

E_T = ________________________

G. Measure the applied voltage. How does it compare with answer in step F?

____

____

H. Using the voltage drops in step E and the measured resistance in step A, compute the current through each resistor. Record the current in the blanks.

1. I_{R_1} = ________________________

2. I_{R_2} = ______________________________

3. I_{R_3} = ______________________________

4. I_{R_4} = ______________________________

I. 1. What is the characteristic of current in series? ____________

____

2. Does the answer to step H agree with that characteristic? ____

____

J. 1. If there was no current flow in step H and power to the circuit was on, the circuit would be (open or short?) ______________

2. If the switch is ON and there is no current flowing because the fuse is blown, what will the voltage drop over the fuse be?

____

____

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PROJECT GUIDE #8--Perform Parallel Circuit Analysis Using Electrical Measuring Devices

PURPOSE: Parallel circuits are used most often because an individual branch can function independently from other branches and each may be diagnosed separately. This project guide will allow you to develop competency in measuring voltage, current, and resistance in a parallel circuit.

EQUIPMENT AND TOOLS NEEDED:

A. Student multimeter

B. Project board

C. Project board components

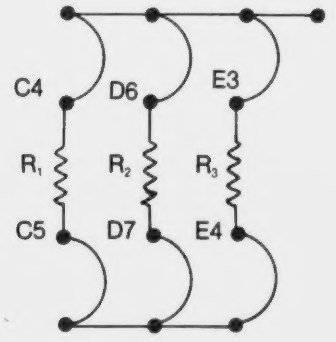
SUPPLIES AND MATERIALS:

A. Resistors

1. R_1 - 390 Ω , 1 watt
2. R_2 - 1100 Ω , 1 watt
3. R_3 - 560 Ω , 1 watt

PROCEDURE:

A. Set up the following circuit on the project board



PROJECT GUIDE #8

B. Use the multimeter to measure the resistance of R_1, R_2, and R_3. Record readings in the blanks

1. R_1 = ______________________
2. R_2 = ______________________
3. R_3 = ______________________

C. Calculate the total resistance of R_1, R_2, and R_3

Calculated R_T = ____________________

D. Record the measured resistance

Measured R_T = ______________________

E. Measure the voltage across each resistor. Record the readings below

1. E_{R_1} = ______________________
2. E_{R_2} = ______________________

F. Measure the current through each branch. Record the readings below

1. I_{R_1} = _________________________ milliamperes
2. I_{R_2} = _________________________ milliamperes
3. I_{R_3} = _________________________ milliamperes

G. Resistor #3 should be included in the next exercise. Record the readings below

1. E_{R_1} = _______________________ volts
2. E_{R_2} = _______________________ volts

H. Measure the current through each branch. Record the readings below

1. I_{R_1} = ________________________

2. I_{R_2} = ________________________

3. I_{R_3} = ________________________

I. Measure the total current R_1, R_2, and R_3. Record the reading below

I_T = ___________________________

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THEORY TEST

1. State Ohm's law.

2. State the principle of Kirchhoff's voltage law.

3. State the principle of Kirchhoff's current law.

4. Arrange in order the steps for properly connecting a voltmeter. Write a "1" in the blank before the first step, a "2" in the blank before the second step, and so on.

____a. Select a scale that will be higher than the known circuit voltage

____b. Determine the approximate voltage of the circuit

____c. Turn circuit power ON

____d. Select the proper AC or DC settting

____e. Connect the voltmeter in parallel

THEORY TEST

5. Arrange in order the steps for properly connecting the ohmmeter. Write a "1" in the blank before the first step, a "2" in the blank before the second step, and so on.

______ a. Turn circuit power OFF

______ b. Connect the ohmmeter probes in series across resistance or wire to be checked

______ c. Select the proper resistance scale

______ d. Zero the ohmmeter

6. Arrange in order the steps for properly connecting an ammeter. Write a "1" in the blank before the first step, a "2" in the blank before the second step, and so on.

______ a. Turn circuit power OFF

______ b. Determine the approximate amperage of the circuit

______ c. Select a scale that will be higher than the known circuit amperage

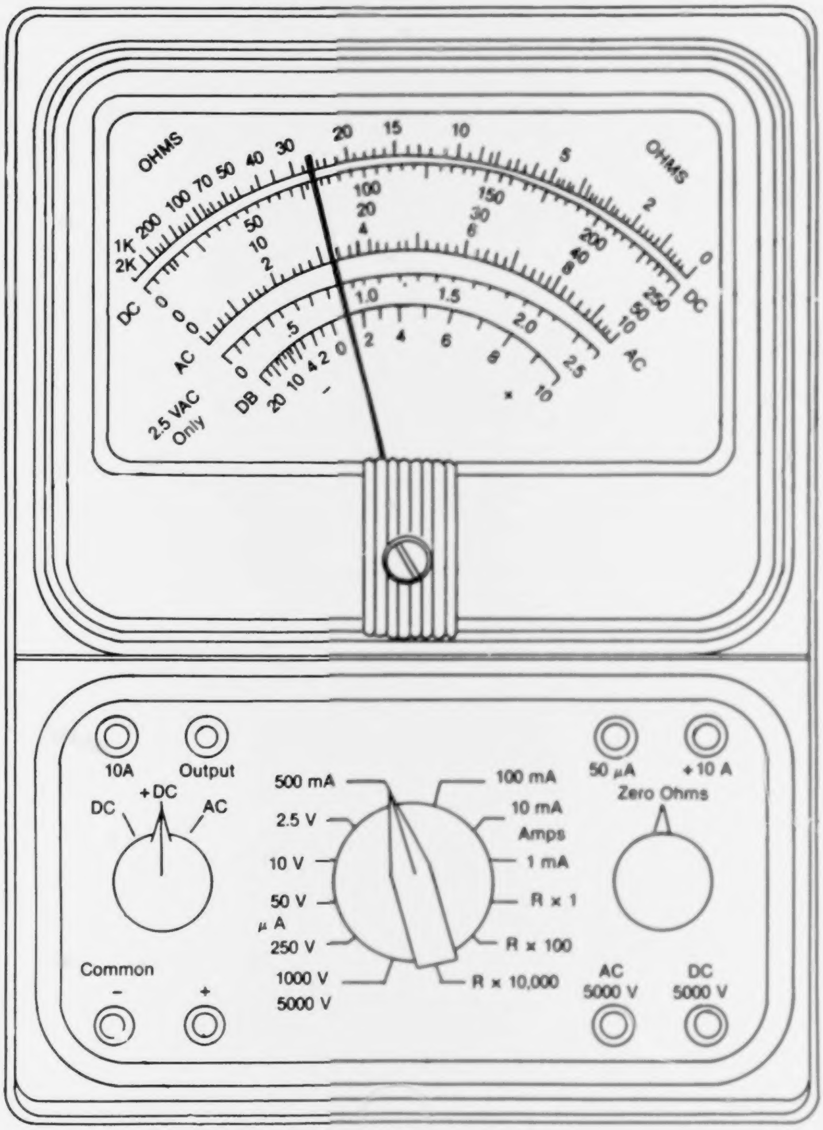
______ d. Connect the ammeter in series

______ e. Select the proper AC or DC setting

______ f. Open the circuit at the point current is to be measured

______ g. Turn circuit power ON

7. Interpret the scales of a multimeter, using the diagram below. Write the correct answers in the blanks on the following page.


OHMS
1K
2K
200
100
70
50
40
30
20
15
10
5
2
0
OHMS
DC
AC
2.5 VAC
Only
DB
100
150
200
250
20
30
40
50
4
6
8
10
50
10
2
1.0
1.5
2.0
2.5
.5
0
20 10 4 2 0 2 4 6 8 10
10A
Output
DC
+DC
AC
Common
500 mA
2.5 V
10 V
50 V
μA
250 V
1000 V
5000 V
100 mA
10 mA
Amps
1 mA
R × 1
R × 100
R × 10,000
50 μA
+10 A
Zero Ohms
AC
5000 V
DC
5000 V

a. When the range selector is set on R x 1, what is the meter reading?

____

b. When the range selector is set on 500 mA, what is the meter reading?

____

c. When the range selector is set on 10 V, what is the meter reading?

____

d. When the range selector is set on R x 100, what is the meter reading?

____

e. When the range selector is set on 10 mA, what is the meter reading?

____

8. Select true statements related to the digital meter. Circle the letter preceding each correct statement.

   a. The low battery symbol appears when approximately 100 hours of battery life remain

   b. To measure voltage select only VAC (V~) function

   c. Resistance measurements are indicated by Ω, kΩ, MΩ in the display

   d. For current measurements up to 10A, use the 10A and COM terminals

   e. A continuous tone sounds if the resistor between the terminal is less than approximately 300 Ω.

9. Analyze an electrical circuit diagram, using Ohm's law and Kirchhoff's current and voltage laws. Write the correct answers in the blanks for the diagram on the following page.

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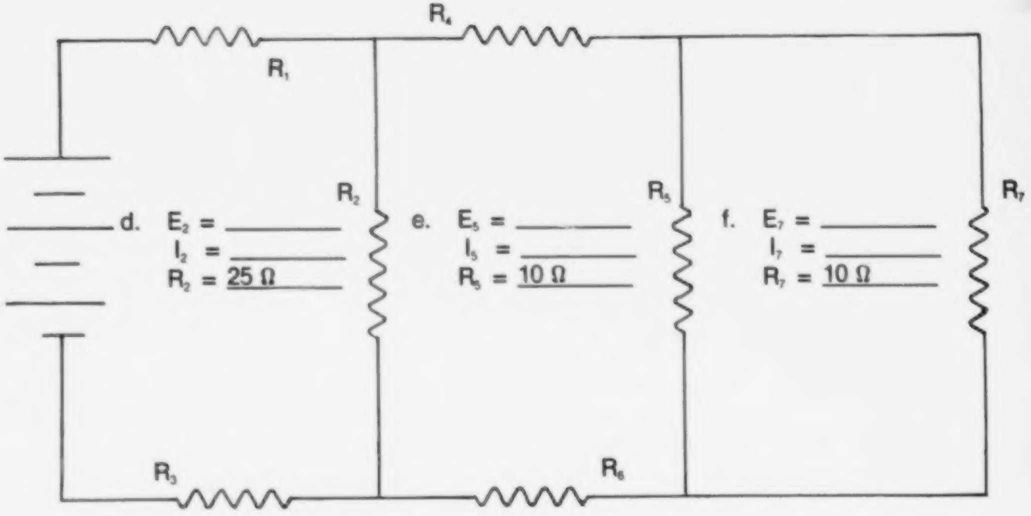
THEORY TEST


R_1
R_2
R_3
R_4
R_5
R_6
R_7

a. E_1 = ________
I_1 = ________
R_1 = 12.5 Ω

b. E_4 = ________
I_4 = ________
R_4 = 10 Ω

c. E_T = 75 V
I_T = ________
R_T = ________

d. E_2 = ________
I_2 = ________
R_2 = 25 Ω

e. E_5 = ________
I_5 = ________
R_5 = 10 Ω

f. E_7 = ________
I_7 = ________
R_7 = 10 Ω

g. E_3 = ________
I_3 = ________
R_3 = 12.5 Ω

h. E_6 = ________
I_6 = ________
R_6 = 10 Ω

THEORY TEST

(NOTE: Test questions 10-17 are project guides. They are an important part of this test. If they have not been completed, check with your instructor.)

10. Construct a circuit from a schematic diagram.
11. Determine continuity of a circuit.
12. Analyze resistors in a circuit.
13. Measure direct current voltage.
14. Measure direct current.
15. Perform circuit analysis using Ohm's law.
16. Perform series circuit analysis using electrical measuring devices.
17. Perform parallel circuit analysis using electrical measuring devices.

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ANSWERS TO THEORY TEST

1. Current in a circuit is directly proportional to the voltage causing it, and inversely proportional to the resistance of the circuit

2. The sum of the voltage drops around a circuit equals the applied voltage

3. The current entering any point or junction is equal to the current leaving that point or junction

4. a. 3
   b. 1
   c. 4
   d. 2
   e. 5

5. a. 3
   b. 4
   c. 1
   d. 2

6. a. 4
   b. 1
   c. 3
   d. 6
   e. 2
   f. 5
   g. 7

7. a. 27 Ω
   b. 158 mA
   c. 3.25 V
   d. 2700 Ω
   e. 3.25 mA

8. a, c, d

ANSWERS TO THEORY TEST

9. a. $E_1 = 25$ V
$E_1 = 2$ A

b. $E_4 = 10$ V
$I_4 = 1$ A

c. $I_T = 2$ A
$R_T = 37.5\,\Omega$

d. $E_2 = 25$ V
$I_2 = 1$ A

e. $E_5 = 5$ V
$I_5 = 0.5$ A

f. $E_7 = 5$ V
$I_7 = 0.5$ A

g. $E_3 = 25$ V
$I_3 = 2$ A

h. $E_6 = 10$ V
$I_6 = 1$ A

10. Performance skills evaluated to the satisfaction of the instructor

11. Performance skills evaluated to the satisfaction of the instructor

12. Performance skills evaluated to the satisfaction of the instructor

13. Performance skills evaluated to the satisfaction of the instructor

14. Performance skills evaluated to the satisfaction of the instructor

15. Performance skills evaluated to the satisfaction of the instructor

16. Performance skills evaluated to the satisfaction of the instructor

17. Performance skills evaluated to the satisfaction of the instructor

MODULE OF INSTRUCTION
FOR
AVIATION MAINTENANCE TECHNOLOGY

GENERAL
G105 AVIATION ELECTRICITY AND ELECTRONICS
READ AND INTERPRET ELECTRICAL CIRCUIT DIAGRAMS
G105-D

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G105 AVIATION ELECTRICITY AND ELECTRONICS
READ AND INTERPRET ELECTRICAL CIRCUIT DIAGRAMS
G105-D

MODULE CONTENTS

A. Introduction and Module Objective

B. Specific Objectives

C. Instructor's Module Implementation Guide

D. Technical Information Supplement #1 - Common Electrical Symbols

E. Workbook Supplements

1. Workbook Supplement #1 - Determine Appropriate Switch and Derating Factors
2. Workbook Supplement #2 - Read Information on a Simple Circuit
3. Workbook Supplement #3 - Read Information on a Large Electrical Schematic
4. Workbook Supplement #4 - Determine Electrical Component Ratings

F. Answers to Workbook Supplements

G. Theory Test

H. Answers to Theory Test

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G105 AVIATION ELECTRICITY AND ELECTRONICS
READ AND INTERPRET ELECTRICAL CIRCUIT DIAGRAMS
G105-D

INTRODUCTION

An aircraft electrical system is like a road map in that it allows the technician to trace the flow of electrons through a series of wires and components. "Chasing the electrons," as it is called, is a very essential part of the technician's ability to troubleshoot and repair electrical components.

MODULE OBJECTIVE

After completion of this module, you will be able to read and interpret aircraft electrical diagrams and schematics and determine normal electrical functions as they relate to switches, fuses, and wire numbering. You will demonstrate this knowledge by completing the procedures outlined in the workbook assignments and by scoring a minimum of 85 percent on the module theory test.

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SPECIFIC OBJECTIVES

After completion of this module, you will be able to:

1. Match common electrical symbols to their correct descriptions. (1)	Technical Supplement #1
2. Interpret a wire/cable size chart. (3)	AC 43.13-1A Ch. 11, Sec. 2-3 EA-ITP-G 2:VIII:22
3. Interpret switch and derating chart to determine appropriate switch and derating factors. (3)	AC 43.13-1A Page 177 AC 43.13-2A Page 177: Par.430 Workbook Supplement #1
4. Interpret information from a schematic diagram and an equipment chart necessary for determining normal circuit operation. (3)	Workbook Supplement #2 Workbook Supplement #3
5. Interpret a wire and circuit protector chart. (3)	AC 43.13-1A Workbook Supplement #4

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INSTRUCTOR'S MODULE IMPLEMENTATION GUIDE

I. Implementation Suggestions

(NOTE: Have students read all material related to the Specific Objectives. Much of this reading can be done as homework assignments.)

Estimated Teaching Time		Theory	Lab
Objective 1	Show samples of electrical drawings that use various symbols. Discuss Technical Information Supplement #1 and stress the importance of learning to identify these basic components. Use various diagrams and sketches on the board to illustrate the use of each symbol.		
Objective 2	Explain wire/cable size charts. Have students read AC 43.13:1A, Chapter 11, sections 2 and 3. Draw several simple circuits on board or make into transparencies. Have students make various calculations. Relate these calculations to larger, more complicated schematics.		
Objective 3	Have students read AC 43.13-1A, page 177 and AC 43.13-2A, page 177, Paragraph 430. Review the specific critical factors. Have students complete Workbook Supplement #1.		

INSTRUCTOR'S MODULE IMPLEMENTATION GUIDE

Estimated Teaching Time		Theory	Lab
Objective 4	Review information relevant to solving problems covered in Workbook Supplements #2 and #3. Have students complete the workbook supplements. Assist as necessary. Make transparencies of the schematics and use them to illustrate or trace circuits so that each student can follow the problem.		
Objective 5	Have students read AC 43.13-1A and discuss the information included. If possible, display actual wiring circuits illustrating the relationships between components. Have students complete Workbook Supplement #4. Encourage students to ask questions and discuss specific points of interest.		

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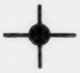
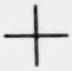
TECHNICAL INFORMATION SUPPLEMENT #1 - Common Electrical Symbols

The following is a listing of the most common electrical symbols. You are expected to learn to identify them in specific applications. There are many other symbols that will require you to refer to various manufacturer's tables.

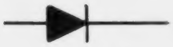
A. Connection



B. No connection

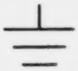


C. Metallic rectifier

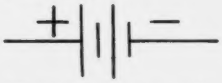


D. Polarity - positive and negative

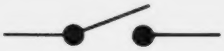
E. Ground



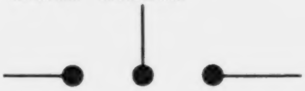
F. Battery



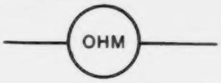
G. Single-pole single-throw switch



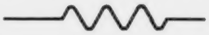
H. Single-pole double-throw switch



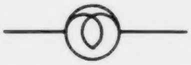
I. Ohmmeter



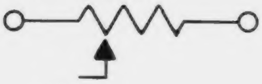
J. Resistor



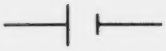
K. Lamp



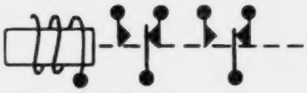
L. Rheostat



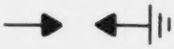
M. Cell



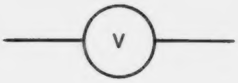
N. Relay coil with contacts



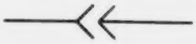
O. Spark plug



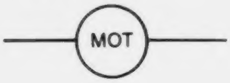
P. Voltmeter



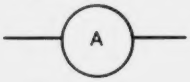
Q. Single Conductor Connector



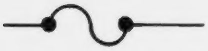
R. Motor



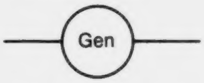
S. Ammeter



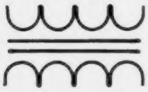
T. Fuse



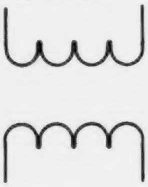
U. Generator



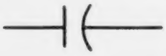
V. Transformer, iron core



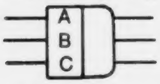
W. Transformer, air core



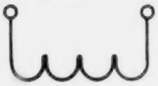
X. Capacitor, fixed



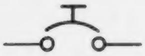
Y. Connector, plug and receptacle (Cannon plug)



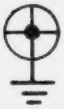
Z. Solenoid



AA. Push-pull circuit breaker



BB. Spark igniter



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WORKBOOK SUPPLEMENT #1 - Determine Appropriate Switch and Derating Factors

In working with various types of switches and derating factors it is important that you learn to make calculations using various charts and standards. The following problems will allow you to further develop competency in this area. Use the chart below to answer the following questions. Write the correct answers in the blanks.

Nominal system voltage	Type of load	Derating factor
24 V.D.C.	Lamp	8
24 V.D.C	Inductive (Relay-Solenoid)	4
24 V.D.C	Resistive (Heater)	2
24 V.D.C.	Motor	3
12 V.D.C.	Lamp	5
12 V.D.C.	Inductive (Relay-Solenoid)	2
12 V.D.C.	Resistive (Heater)	1
12 V.D.C.	Motor	2

A. A switch to be used in an incandescent lamp with a 24-volt current has a derating factor of ____________________.

B. A 12-volt system contains a 3 amp lamp. What is the derating factor?

____

(NOTE: To find the nominal rating of a switch to operate a given device, multiply the continuous load current by the derating factor.)

C. For conditions in question B, what would be the minimum nominal switch rating? ____

(NOTE: To find the continuous load current that a switch or a given nominal switch rating will handle efficiently, divide the minimum nominal switch rating by the derating factor.)

D. A switch has a nominal rating of 50 amps. What is the maximum continuous lamp current with which this switch can be used in a 24-volt circuit?

____

____

WORKBOOK SUPPLEMENT #1

E. In the situation outlined in question D, what is the maximum current a solenoid can draw? ____

____

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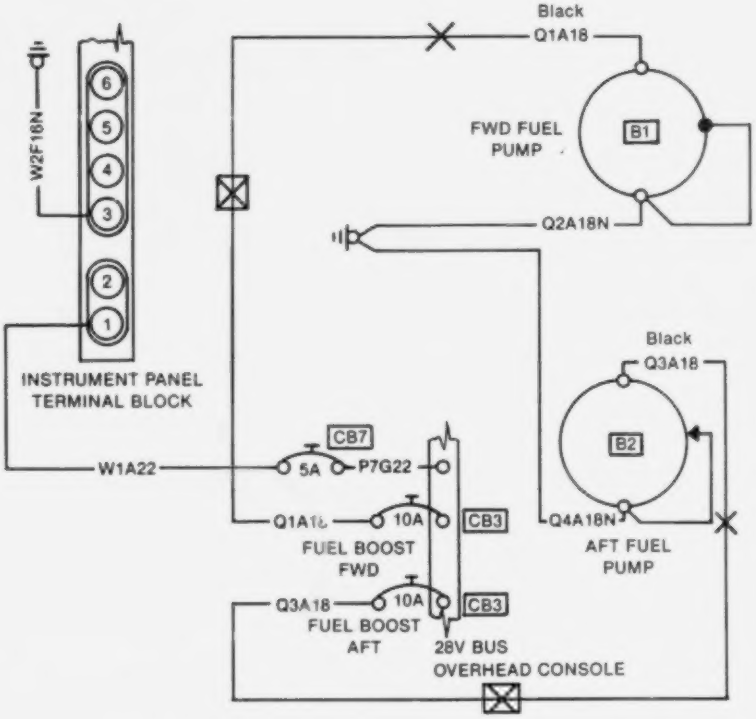
WORKBOOK SUPPLEMENT #2 - Read Information on a Simple Circuit

It is critically important that the A & P technician be able to pull information from electrical schematics. This information is used to make decisions and troubleshoot problems. Study the schematic of a simple electrical circuit below and answer the following questions. Write the correct answers in the blanks.



Black
Q1A18
FWD FUEL PUMP
B1
Q2A18N
W2F16N
6
5
4
3
2
1
INSTRUMENT PANEL TERMINAL BLOCK
Black
Q3A18
B2
CB7
W1A22
5A
P7G22
Q1A18
10A
CB3
FUEL BOOST FWD
Q4A18N
AFT FUEL PUMP
Q3A18
10A
CB3
FUEL BOOST AFT
28V BUS
OVERHEAD CONSOLE

Adapted with permission of Bell Helicopter Company, P.O. Box 482, Ft. Worth, Texas 76101.

A. How many circuit protectors are on this print? ______________________________

B. What are the wire numbers on each?

1. ________________

2. ________________

3. ________________

WORKBOOK SUPPLEMENT #2

C. Where is the 28 V bus bar located? ______________________________

D. Does CB7 control a fuel pump? ______________________________

E. What does wire number W2F16N control? ______________________________

____

F. If there is an open circuit in wire number Q2A18N, how will this affect the circuit? ______________________________

____

G. What type of circuit or circuits does this print have?

____

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WORKBOOK SUPPLEMENT #3 - Read Information on a Large Electrical Schematic

Schematics are often very difficult and quite involved and as a result require a keen understanding of various components. This exercise will help prepare the A & P technician in the interpretation of a very realistic set of problems. Use the fold-out blueprint at the end of this supplement to answer the following questions. Write the correct answers in the blanks.

A. How many engines does this aircraft have? ______________________

B. Draw the current path from bus to ground for the bank and turn indicator and label all wires and connections on the drawing.

C. What 4 circuits draw current from the battery that will not be shown on the ammeter?

1. ______________________________________
2. ______________________________________
3. ______________________________________
4. ______________________________________

D. Do the position lights have a flash position? ____________________

WORKBOOK SUPPLEMENT #3

E. What circuit on the bus bar has no circuit breaker? ____________________

____

F. 1. Can any light be dimmed? ____

2. If yes, which light(s)? If no, why not? __________________________

____

G. What is the configuration of the airplane in this diagram?

____

____

H. Draw the current path from ground through the landing gear solenoid to the bus.

WORKBOOK SUPPLEMENT #3

I. Draw the rotating beacon circuit and label all wire segments.

J. What wire connects the right generator to the voltage regulator?

____

K. Draw the cigar lighter circuit.

L. How many circuit protectors are in this circuit? ____________________

M. Draw the current path from the ground through the landing gear field and armature to the bus when the gear selector is placed in the UP position.

N. 1. If the gear handle was placed in the UP position while the aircraft was on the ground and the master switch turned ON, would the gear retract?

____

2. Why? ____

O. The aircraft is flying with the gear retracted. What would happen if the throttles are returned to idle? ______________________________

____

WORKBOOK SUPPLEMENT #3

P. Draw the current path through warning horn from ground to bus and label all wires.

WORKBOOK SUPPLEMENT #3

Q. Draw the circuit from bus to ground for the pitot heater.

R. What is the rating for the circuit breakers in the pitot heaters?

____

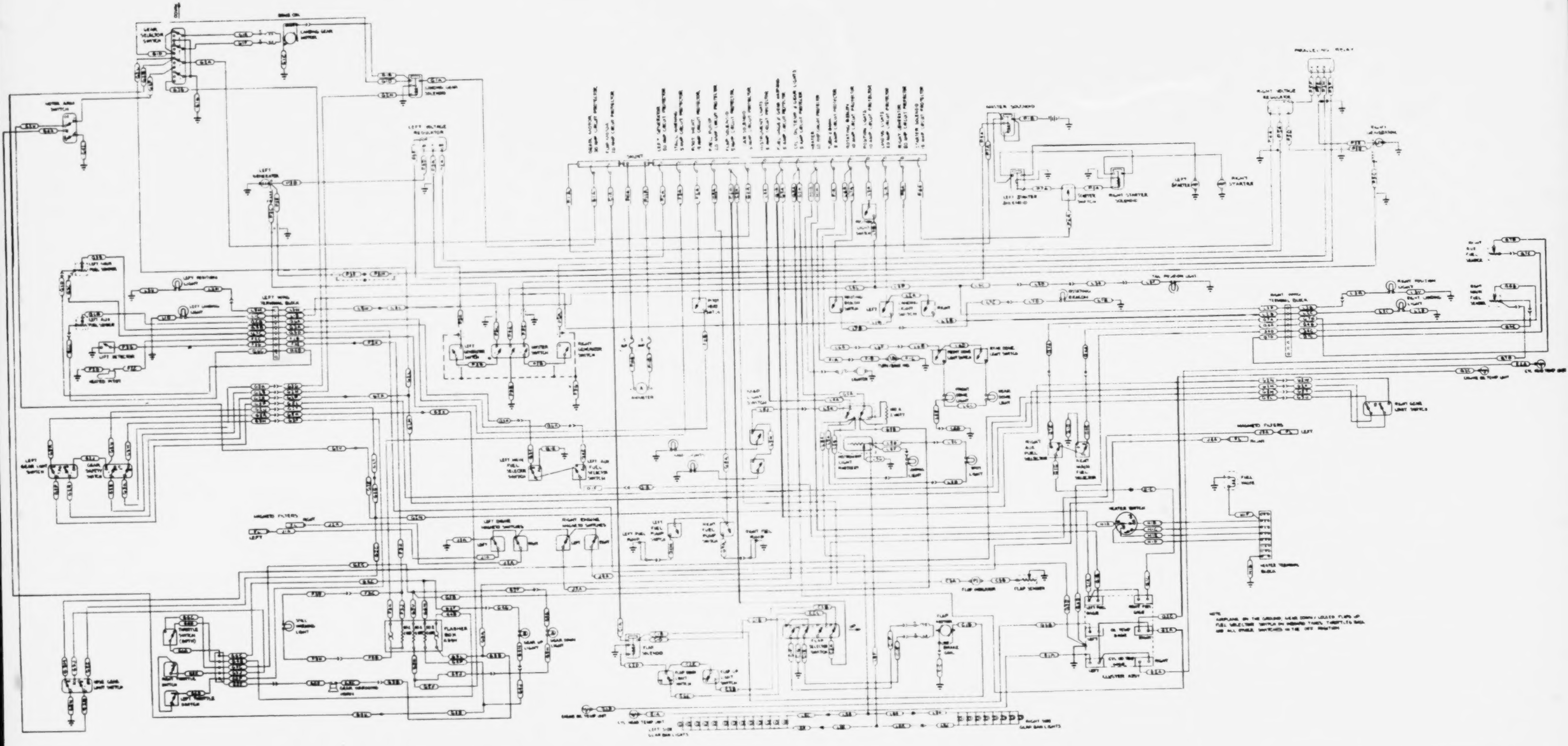
S. Draw the circuit for the lift detector.

T. What type of motor is used in the flap system? ______________________________

____

U. If the 20-amp heater circuit breakers trip, what equipment will be inoperative? ____

V. If the rotating beacon circuit breakers trip, what equipment will be inoperative? ____



Electrical Wiring Diagram

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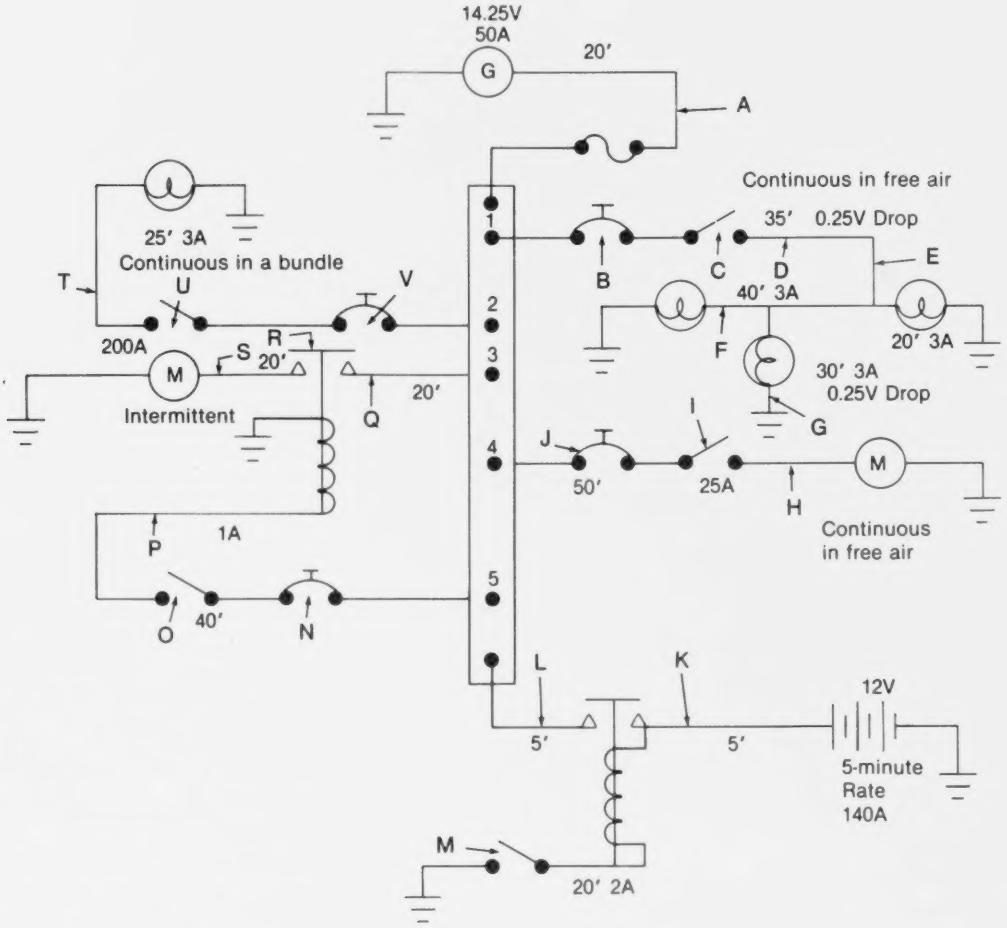
WORKBOOK SUPPLEMENT #4 - Determine Electrical Component Ratings

The A&P technician will often find it necessary to make various mathematical calculations to determine values for wire size and component amp size. The following exercise will allow you to develop the knowledge and skill required to use formulas and reference materials to perform those calculations. Determine values for wire size and for component amp size for the items indicated. Write the correct answers in the corresponding blanks on the answer sheet.


14.25V
50A
G
20′
A
Continuous in free air
35′ 0.25V Drop
1
B
C
D
E
40′ 3A
F
20′ 3A
30′ 3A
0.25V Drop
G
25′ 3A
Continuous in a bundle
T
U
V
2
200A
R
S
20′
M
3
Intermittent
Q
20′
4
J
50′
I
25A
H
M
Continuous
in free air
P
1A
5
O
40′
N
L
K
12V
5′
5′
5-minute
Rate
140A
M
20′ 2A

WORKBOOK SUPPLEMENT #4

A. ____________________

B. ____________________

C. ____________________

D. ____________________

E. ____________________

F. ____________________

G. ____________________

H. ____________________

I. ____________________

J. ____________________

K. ____________________

L. ____________________

M. ____________________

N. ____________________

O. ____________________

P. ____________________

Q. ____________________

R. ____________________

S. ____________________

T. ____________________

U. ____________________

V. ____________________

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ANSWERS TO WORKBOOK SUPPLEMENTS

Workbook Supplement #1

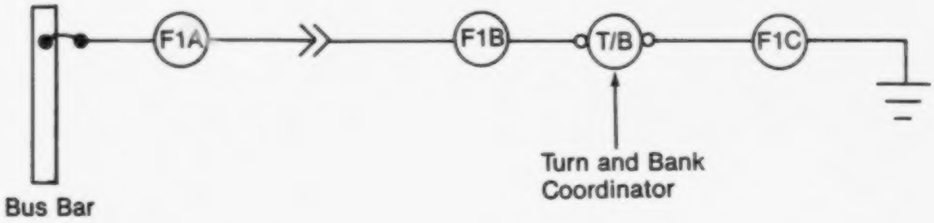
A. 8
B. 5
C. 15 A
D. 6.25 A
E. 12.5 A

Workbook Supplement #2

A. 3
B. 1. W1A22
   2. Q3A18
   3. Q1A18
C. Overhead console
D. No
E. Ground for pin 3 through 6 on terminal block
F. Forward fuel pump will not operate
G. Series

Workbook Supplement #3

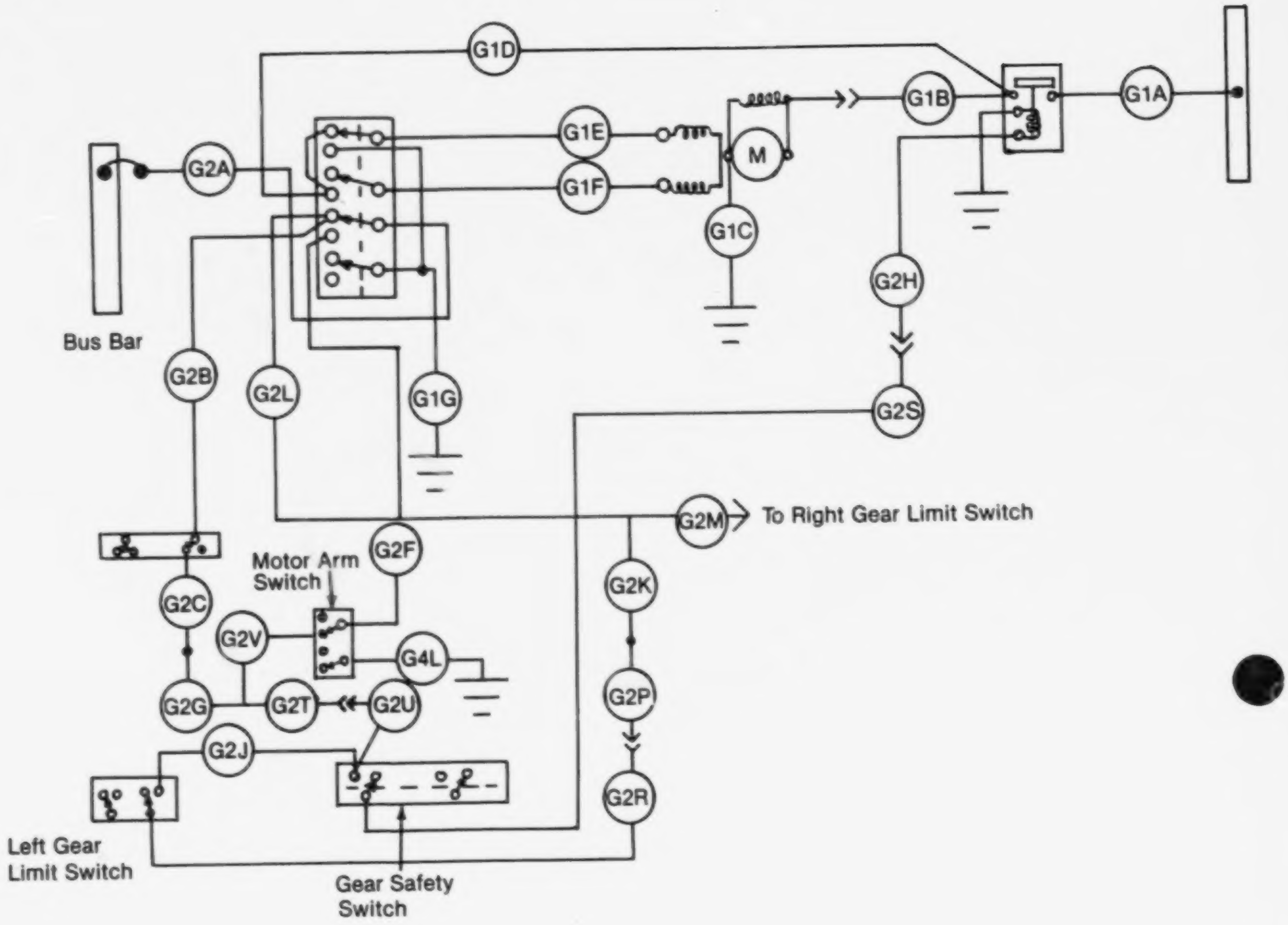
A. 2
B.



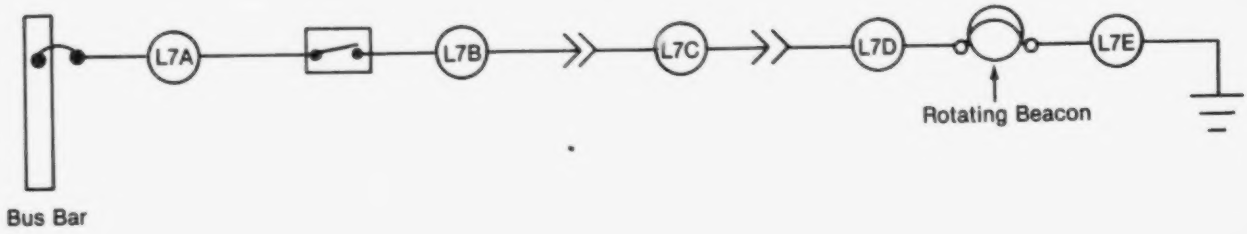
C. 1. Left starter
   2. Right starter
   3. Flap motor
   4. Gear motors
D. No
E. PIA - battery
F. 1. Yes
   2. Spot light, compass light, glare ban lights
G. Gear is down, flaps are up, fuel selectors are on in board tanks, throttle is at idle, and all other switches are off

ANSWERS TO WORKBOOK SUPPLEMENTS

H.


G1D
G1B
G1A
G2A
G1E
G1F
M
G1C
G2H
Bus Bar
G2B
G2L
G1G
G2S
G2M
To Right Gear Limit Switch
G2F
G2K
Motor Arm Switch
G2C
G2V
G4L
G2P
G2G
G2T
G2U
G2J
G2R
Left Gear Limit Switch
Gear Safety Switch

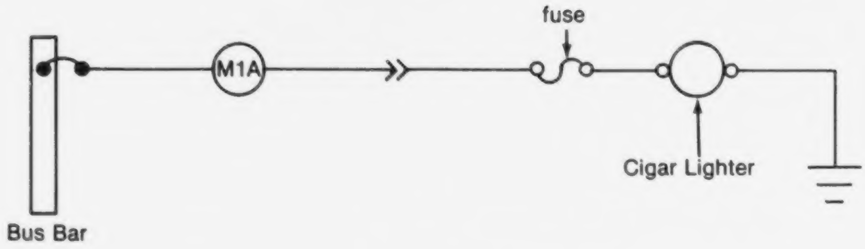
I.


L7A
L7B
L7C
L7D
L7E
Rotating Beacon
Bus Bar

ANSWERS TO WORKBOOK SUPPLEMENTS

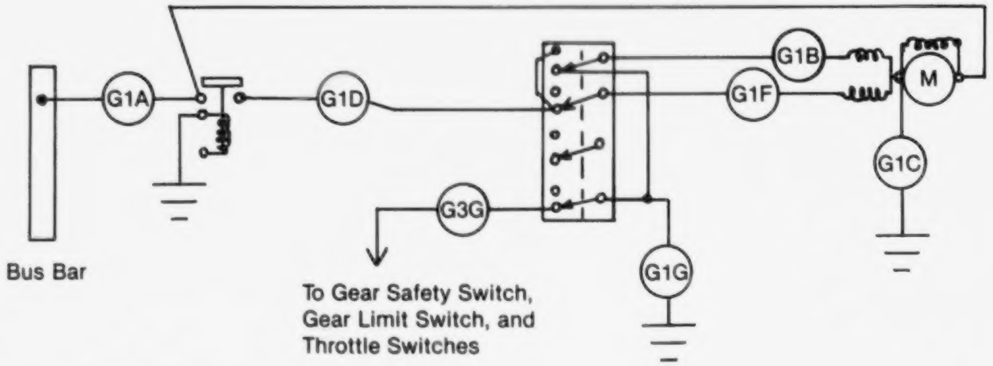
J. P5I

K.


fuse
M1A
Cigar Lighter
Bus Bar

L. 2

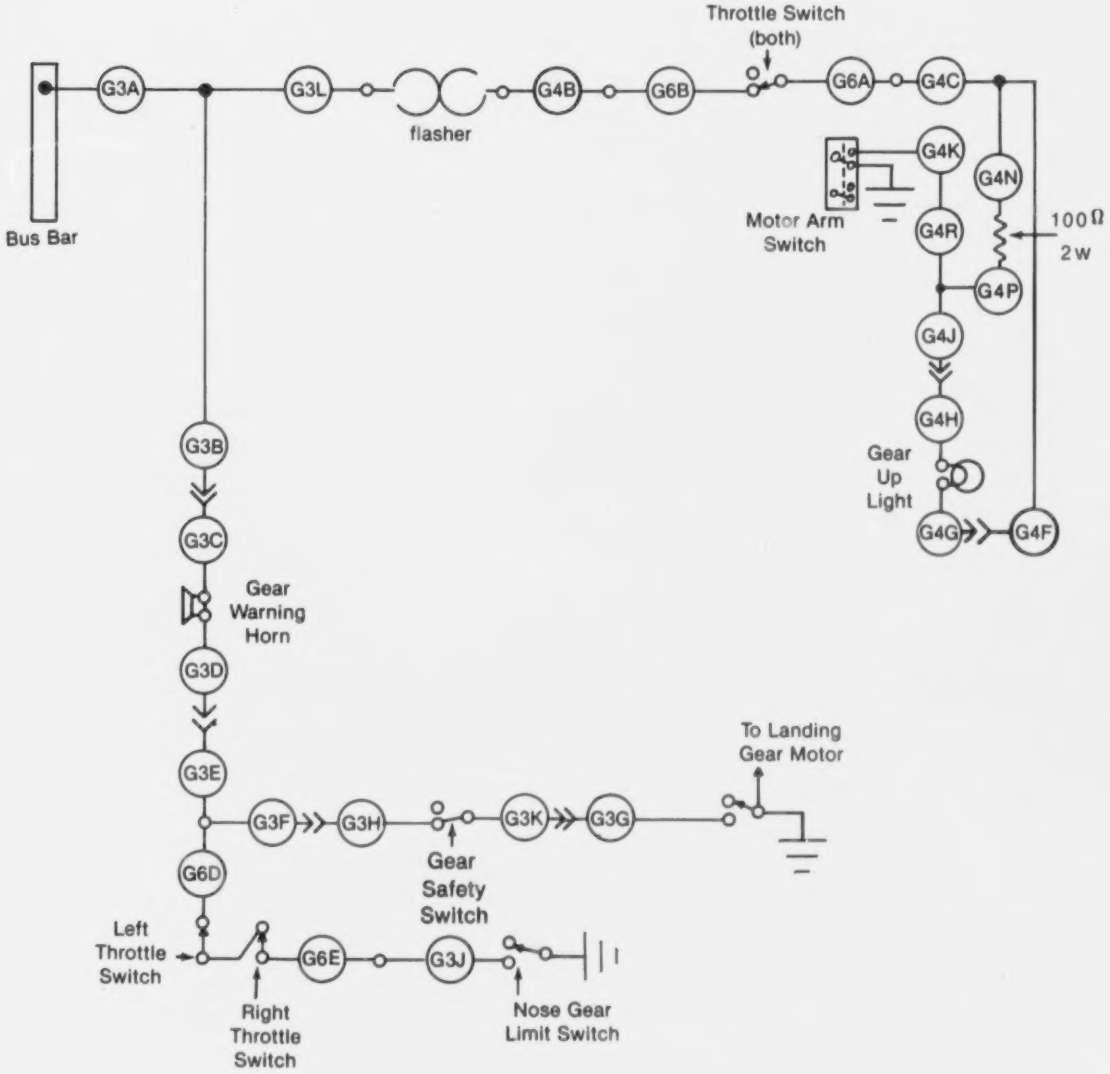
M.


G1A
G1D
G1B
G1F
M
G1C
G3G
G1G
Bus Bar
To Gear Safety Switch, Gear Limit Switch, and Throttle Switches

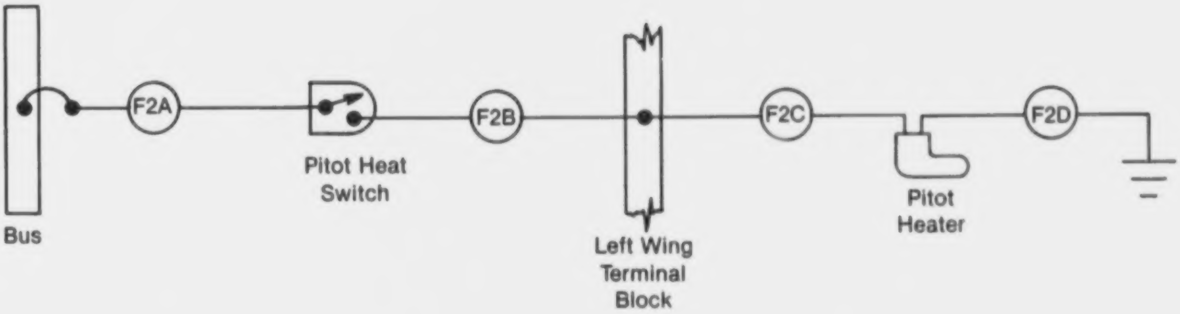
N. 1. No
   2. Squat switch would keep landing gear solenoid from energizing

O. Warning horn would sound

P.

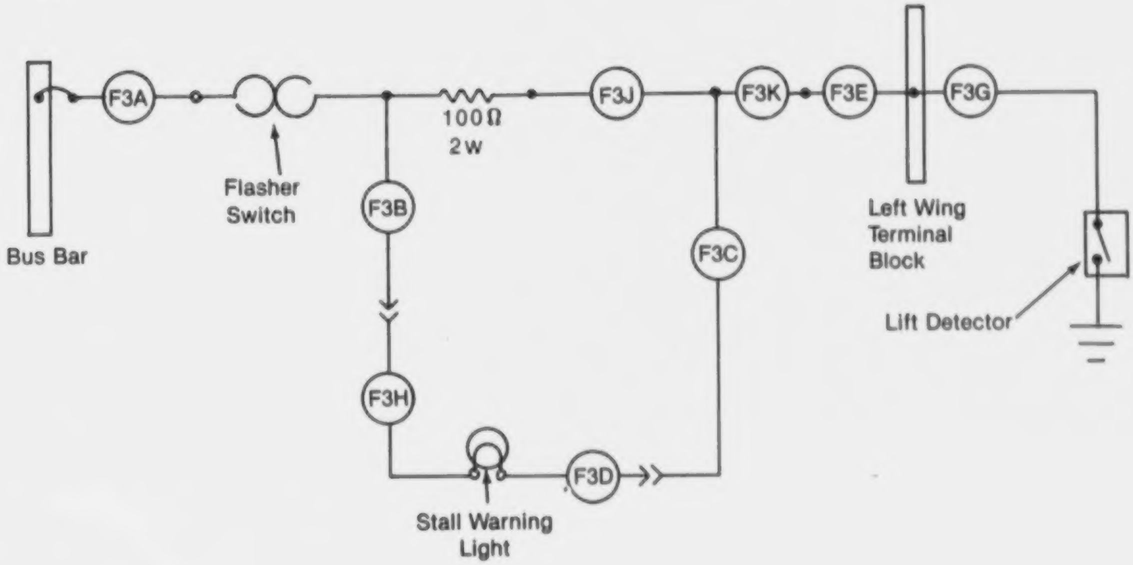

Throttle Switch (both)
Bus Bar
G3A
G3L
flasher
G4B
G6B
G6A
G4C
G4K
Motor Arm Switch
G4N
100 Ω
2 w
G4R
G4P
G4J
G4H
Gear Up Light
G4G
G4F
G3B
G3C
Gear Warning Horn
G3D
G3E
To Landing Gear Motor
G3F
G3H
G3K
G3G
Gear Safety Switch
G6D
Left Throttle Switch
Right Throttle Switch
G6E
G3J
Nose Gear Limit Switch

Q.


F2A
F2B
F2C
F2D
Bus
Pitot Heat Switch
Left Wing Terminal Block
Pitot Heater

R. 15 A

S.


F3A
F3J
F3K
F3E
F3G
100Ω
2 w
Flasher Switch
Bus Bar
F3B
F3C
F3H
F3D
Left Wing Terminal Block
Lift Detector
Stall Warning Light

T. DC reversible motor with brake

U. Heater, cigar lighter

V. Rotating beacon, front and rear dome lights

ANSWERS TO WORKBOOK SUPPLEMENTS

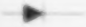
Workbook Supplement #4

A. #2 ga
B. 20 A
C. 45 A
D. 8 ga
E. 14 ga
F. 12 ga
G. 14 ga
H. 4 ga
I. 50 A
J. 100 A
K. #2 ga
L. #2 ga
M. 4 A
N. 7.5 A
O. 2 A
P. 20 ga
Q. 4 ga
R. 400 A
S. 4 ga
T. 16 ga
U. 15 A
V. 15 A

GENERAL
G105 AVIATION ELECTRICITY AND ELECTRONICS
READ AND INTERPRET ELECTRICAL CIRCUIT DIAGRAMS
G105-D

THEORY TEST

1. Match common electrical symbols to their correct descriptions. Write the correct numbers in the blanks.

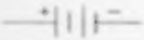
____ a. 

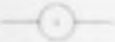
____ b.

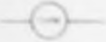
____ c.

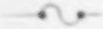
____ d.

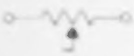
____ e.

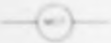
____ f. 

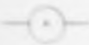
____ g. 

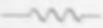
____ h. 

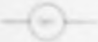
____ i. 

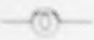
____ j. 

____ k. 

____ l. 

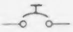
____ m. 

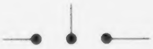
____ n. 

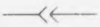
____ o. 

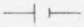
1. Polarity - positive and negative
2. Ground
3. Lamp
4. Connection
5. No connection
6. Metallic rectifier
7. Battery
8. Fuse
9. Generator
10. Motor
11. Resistor
12. Rheostat
13. Voltmeter
14. Ammeter
15. Ohmmeter

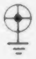
THEORY TEST

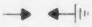
_____p. 

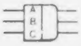
_____q. 

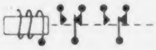
_____r. 

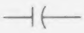
_____s. 

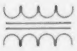
_____t. 

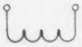
_____u. 

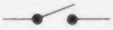
_____v. 

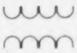
_____w. 

_____x. 

_____y. 

_____z. 

____aa. 

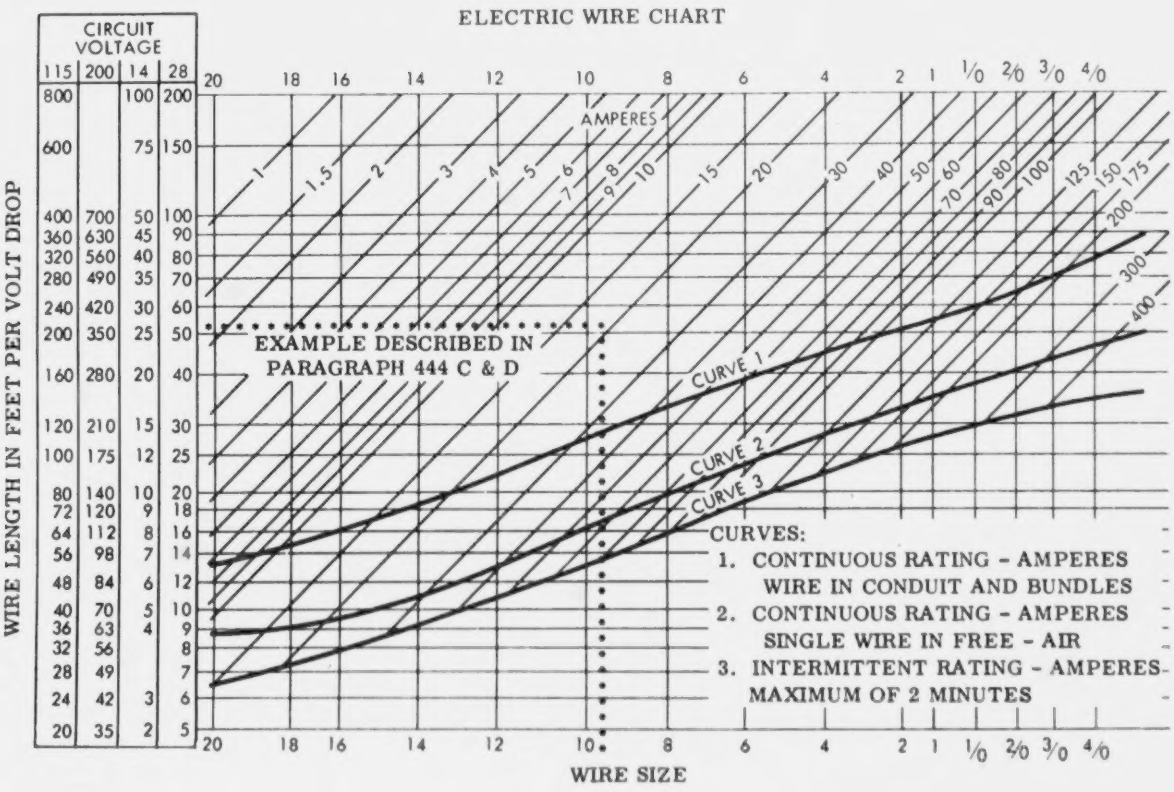
____bb. 

16. Single conductor connector
17. Single-pole single-throw switch
18. Single-pole double-throw switch
19. Push-pull circuit breaker
20. Capacitor, fixed
21. Transformer, air core
22. Transformer, iron core
23. Relay coil with contacts
24. Solenoid
25. Cell
26. Spark igniter
27. Spark plug
28. Connector, plug and receptacle (Cannon plug)

THEORY TEST

2. Interpret the wire/cable size chart below to determine the wire size for the following situation. In a 28-volt system you are installing a 20-amp load that is exactly 25 feet from the bus. What is the correct size? Write the correct answer in the blank.

____



3. Interpret the following switch and derating chart to determine the minimum nominal switch rating for a 24-volt DC motor that draws 15 amps. Write the correct minimum nominal switch rating in the blank.

____

Nominal system voltage	Type of load	Derating factor
24 V.D.C.	Lamp	8
24 V.D.C.	Inductive (Relay-Solenoid)	4
24 V.D.C.	Resistive (Heater)	2
24 V.D.C.	Motor	3
12 V.D.C.	Lamp	5
12 V.D.C.	Inductive (Relay-Solenoid)	2
12 V.D.C.	Resistive (Heater)	1
12 V.D.C.	Motor	2

4. Interpret information from the following schematic diagram and equipment chart. Answer the following questions and write the correct answers in the blanks.

   a. Where are the circuit protectors located? ____________________

   ____

   b. How many circuit protectors are on this print? ____________________

   c. With the relay in the position shown, is the landing light circuit open or closed? ____________________

   d. What is the advantage of this type of switch arrangement?

   ____

   ____

THEORY TEST

e. The landing light circuit is series parallel. (True or False)

____

f. If wire number L5A12 became shorted to ground while the circuit was in operation, what would be the result? ____________________

____

____

g. With the switch in the operating position, if wire number L3A22 became grounded, how would this affect the circuit operation? __________

____

____

h. Draw a neat and complete diagram of the landing light circuit.

i. What is the landing light part number? ____________________

j. What is the name and part number of K8? ____________________

THEORY TEST

EQUIPMENT CHART

ITEM NO.	DESCRIPTION	TYPE OR PART NO.	NO. REQ.
CB5	Circuit Breaker - Trip-Lever	MS24509-5	2
CB2	Circuit Breaker	MS22073-5	2
CB4	Circuit Breaker	MS25244-25	1
DS2	Position Light (Right)	A1285-G7512-24	1
DS3	Position Light (Left)	A1285-R7512-24	1
DS4	Tail Light	A2064-1683	1
DS5	Anti Collision Light	17277-1-28V - Aeroflash	1
DS6	Cockpit Light	15-0007-43 - Grimes	1
DS7	Landing Light	206-075-303-1	1
DS8	Landing Light	206-075-303-1	1
DS9	Edge Light	MS25010315A327	1
DS10	Edge Light	MS25010315A327	1
DS11	Edge Light	MS25010315A327	1
J24	Tail Boom Disconnect	MS3114F12-3S	1
K8	Landing Light Relay	MS2416601	1
P24	Tail Boom Disconnect	MS3116F12-3P	1
Q1	Dimmer Element	L-129-1	1
R-5	Dimming Resistor	M500-OAC-1	1
S18	Landing Light Switch	MS35058-23	1
TB6	Instrument Light Term. Block	MS27212-6	1
TB7	Position Lt. Terminal Block	MS27212-1	1
TB9	Tail Light Terminal Block	MS27212-2	1
Z6	Flasher Unit	17221-1-28V	1
△3	Light Assembly	A6745-24	6
△2	Light Assembly	A6815-24	9
△1	Light Shield	B6618	2

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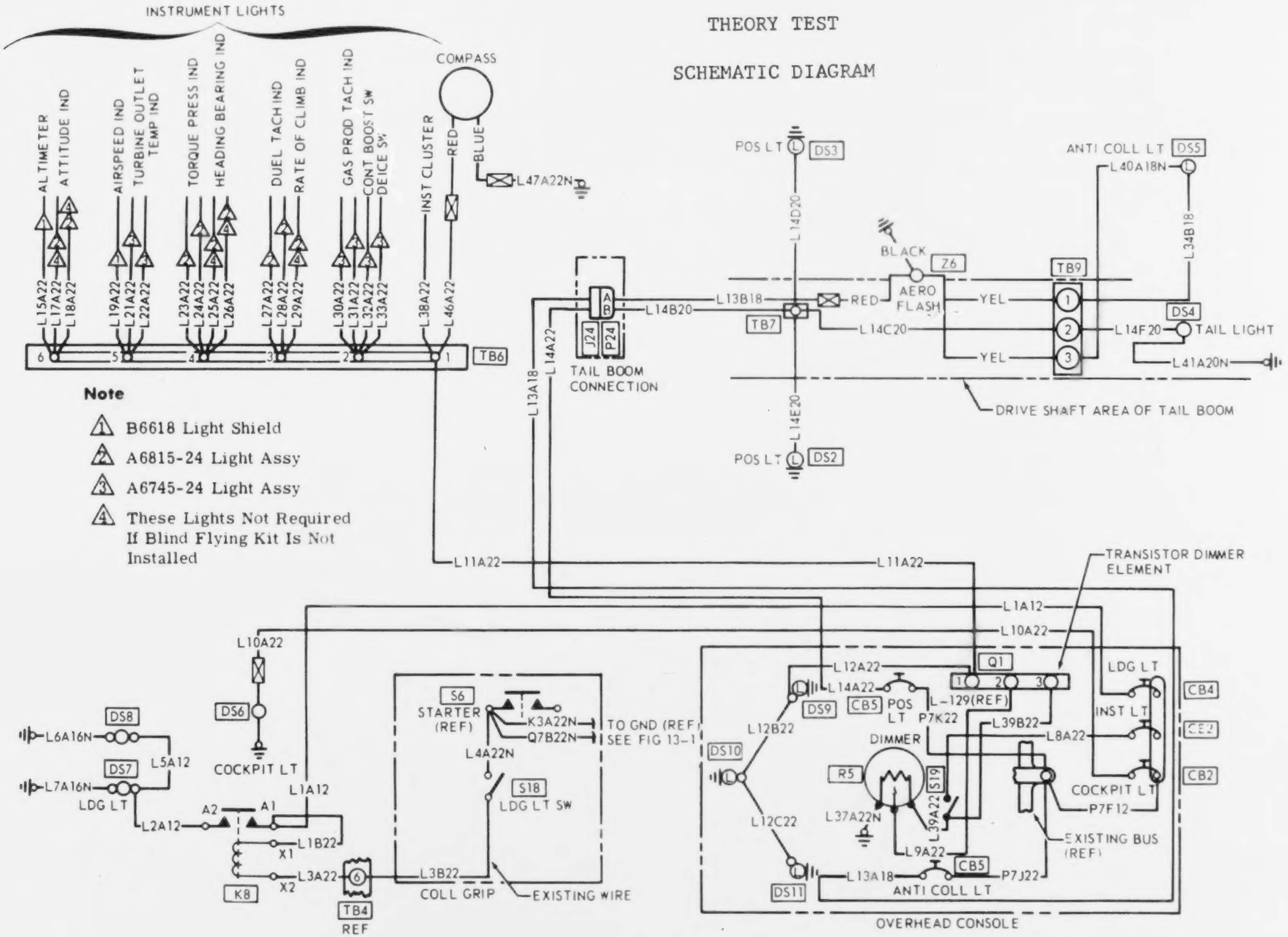
THEORY TEST

SCHEMATIC DIAGRAM

G105D-43



INSTRUMENT LIGHTS
ALTIMETER
ATTITUDE IND
AIRSPEED IND
TURBINE OUTLET TEMP IND
TORQUE PRESS IND
HEADING BEARING IND
DUEL TACH IND
RATE OF CLIMB IND
GAS PROD TACH IND
CONT BOOST SW
DEICE SW
INST CLUSTER
COMPASS
RED
BLUE
L47A22N
L15A22
L17A22
L18A22
L19A22
L21A22
L22A22
L23A22
L24A22
L25A22
L26A22
L27A22
L28A22
L29A22
L30A22
L31A22
L32A22
L33A22
L38A22
L46A22
6
5
4
3
2
1
TB6
POS LT
DS3
L14D20
L14E20
POS LT
DS2
BLACK
Z6
AERO FLASH
RED
YEL
YEL
L13B18
L14B20
TB7
L14C20
A
B
J24
P24
TAIL BOOM CONNECTION
L13A18
L14A22
ANTI COLL LT
DS5
L40A18N
L34B18
TB9
1
2
3
DS4
L14F20
TAIL LIGHT
L41A20N
DRIVE SHAFT AREA OF TAIL BOOM
L11A22
L11A22
TRANSISTOR DIMMER ELEMENT
L1A12
L10A22
L10A22
DS6
COCKPIT LT
DS8
L6A16N
L5A12
DS7
L7A16N
LDG LT
L2A12
A2
A1
L1A12
L1B22
X1
L3A22
X2
K8
6
TB4
REF
S6
STARTER (REF)
K3A22N
Q7B22N
TO GND (REF)
SEE FIG 13-1
L4A22N
S18
LDG LT SW
L3B22
COLL GRIP
EXISTING WIRE
L12A22
Q1
1
2
3
L14A22
DS9
CB5
POS LT
L-129(REF)
P7K22
L39B22
L8A22
DS10
L12B22
DIMMER
R5
S19
L37A22N
L39A22
L9A22
L12C22
DS11
L13A18
CB5
ANTI COLL LT
P7J22
LDG LT
CB4
INST LT
CB2
COCKPIT LT
CB2
P7F12
EXISTING BUS (REF)
OVERHEAD CONSOLE

Note

1. B6618 Light Shield
2. A6815-24 Light Assy
3. A6745-24 Light Assy
4. These Lights Not Required If Blind Flying Kit Is Not Installed

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5. Interpret the wire and circuit protector chart below and answer the following questions. Write the correct answers in the blanks.

a. Does the information given below apply to aluminum wire? ____________

b. What fuse size is required for an AN22 wire? ____________

c. What circuit breaker size is required for an AN22 wire? ____________

d. What fuse is required for an AN4 wire? ____________

e. What circuit breaker size is required for an AN4 wire? ____________

Wire and circuit protector chart.

Wire AN gauge copper	Circuit breaker amp.	Fuse amp.
22	5	5
20	7.5	5
18	10	10
16	15	10
14	20	15
12	25 (30)	20
10	35 (40)	30
8	50	50
6	80	70
4	100	70
2	125	100
1		150
0		150

Figures in parentheses may be substituted where protectors of the indicated rating are not available.

Basis of chart:

(1) Wire bundles in 135° F. ambient and altitudes up to 30,000 feet.

(2) Wire bundles of 15 or more wires, with wires carrying no more than 20 percent of the total current-carrying capacity of the bundle as given in Specification MIL-W-5088 (ASG).

(3) Protectors in 75° to 85° F. ambient.

(4) Copper wire Specification MIL-W-5086 (ASG) or equivalent.

(5) Circuit breakers to Specification MIL-C-5809 or equivalent.

(6) Fuses to Specification MIL-F-15160 or equivalent.

GENERAL
G105 AVIATION ELECTRICITY AND ELECTRONICS
READ AND INTERPRET ELECTRICAL CIRCUIT DIAGRAMS
G105-D

ANSWERS TO THEORY TEST

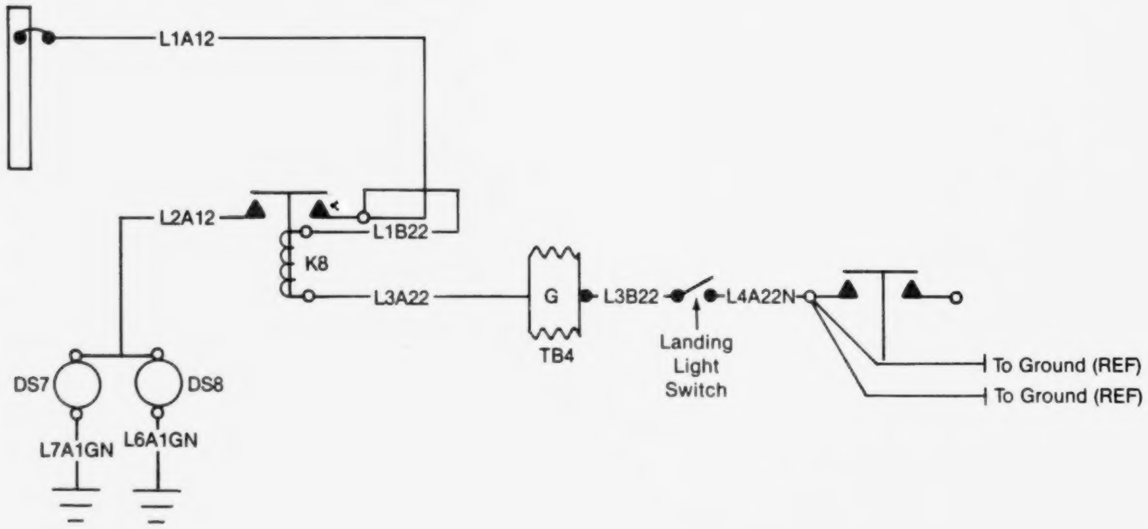
1. a. 6
   b. 5
   c. 2
   d. 1
   e. 4
   f. 7
   g. 13
   h. 15
   i. 8
   j. 12
   k. 10
   l. 14
   m. 11
   n. 9
   o. 3
   p. 19
   q. 18
   r. 16
   s. 25
   t. 26
   u. 27
   v. 28
   w. 23
   x. 20
   y. 22
   z. 24
   aa. 17
   bb. 21

2. #12 wire

3. 45 A

4. a. Overhead console
   b. 5
   c. Open
   d. A low power circuit can control a high power circuit
   e. True
   f. Circuit breaker would pop
   g. Lights would stay on and would not turn off

h.


L1A12
L2A12
L1B22
K8
L3A22
G
TB4
L3B22
L4A22N
Landing Light Switch
To Ground (REF)
To Ground (REF)
DS7
DS8
L7A1GN
L6A1GN

i. 206-075-303-1
j. Landing light relay MS2416601

5. a. Yes
   b. 5 A
   c. 5 A
   d. 70 A
   e. 100 A

MODULE OF INSTRUCTION
FOR
AVIATION MAINTENANCE TECHNOLOGY

GENERAL
G105 AVIATION ELECTRICITY AND ELECTRONICS
INSPECT AND SERVICE BATTERIES
G105-E

GENERAL
G105 AVIATION ELECTRICITY AND ELECTRONICS
INSPECT AND SERVICE BATTERIES
G105-E

MODULE CONTENTS

A. Introduction and Module Objective

B. Specific Objectives

C. Instructor's Module Implementation Guide

D. Technical Information Supplements

   1. Technical Information Supplement #1 - Terms and Definitions
   2. Technical Information Supplement #2 - Lead-Acid Battery Safety Precautions
   3. Technical Information Supplement #3 - Nickel-Cadmium Battery Safety Precautions

E. Transparency Masters

   1. TM #1 - Lead-Acid Battery Chemical Composition
   2. TM #2 - Chemical Activity During Charging
   3. TM #3 - The Hydrometer
   4. TM #4 - Specific Gravity Correction Chart
   5. TM #5 - Nickel-Cadmium Battery Cell Construction

F. Project Guides

   1. Project Guide #1 - Inspect and Service Lead-Acid Battery
   2. Project Guide #2 - Inspect and Service Nickel-Cadmium Battery

G. Theory Test

H. Answers to Theory Test

I. Practical Test

   1. Practical Test #1 - Inspect and Service Lead-Acid Battery
   2. Practical Test #2 - Inspect and Service Nickel-Cadmium Battery

GENERAL
G105 AVIATION ELECTRICITY AND ELECTRONICS
INSPECT AND SERVICE BATTERIES
G105-E

INTRODUCTION

Aircraft batteries do not provide power for the normal functioning of electrical systems in flight, nor do they actually make or even store electricity. Batteries change electrical energy into chemical energy and store it in this form until it is needed to operate the starter, meet intermittent current demands greater than the generator or alternator can handle, or provide auxiliary power when the generator is not operating. Today's high-output batteries are long lasting and reliable, but they are also potentially hazardous. Knowledge of how these batteries work and the proper methods for servicing them is essential to safe and proper performance both on the ground and in the air.

MODULE OBJECTIVE

After completion of this module, you will be able to describe the types, uses, and maintenance of primary and secondary battery cells. You will also be able to inspect and service secondary battery cells and check battery cells for electrical leakage. You will demonstrate this knowledge by completing the procedures outlined in the workbook assignments and project guides. You will further demonstrate this knowledge by scoring a minimum of 85 percent on the module theory test and by meeting airworthiness standards on the module practical tests.

GENERAL
G105 AVIATION ELECTRICITY AND ELECTRONICS
INSPECT AND SERVICE BATTERIES
G105-E

SPECIFIC OBJECTIVES

After completion of this module you will be able to:

1. Match terms related to aircraft batteries to their correct definitions. (1)	Technical Supplement #1	
2. Match common types of batteries to their general classifications. (1)	EA-ITP-G	2:X:40-42
3. Select true statements related to the internal construction and electrical characteristics of a lead-acid battery. (1)	EA-ITP-G AC-65-9A	2:X:40-42 306-310
4. Determine the state of charge of a lead-acid battery. (2)	EA-ITP-G AC-65-9A	2:X:42-44 310-313
5. State the properties used to rate the design performance of aircraft batteries. (1)	EA-ITP-G AC-65-9A	2:X:43 310
6. State the characteristics of a properly maintained lead-acid battery. (1)	EA-ITP-G EA-ITP-GW AC-65-9A	2:X:44-45 2:15, #1,#21 311
7. Distinguish between the characteristics of voltage and current relative to the constant-current and constant-voltage charging systems. (1)	EA-ITP-G AC 65-9 313	2:X:45-46
8. Select true statements related to safety precautions used during lead-acid battery charging. (1)	EA-ITP-G Technical Supplement #2 ITP-G2	2:X:45,46 Program 6
9. Inspect and service a lead-acid battery. (3)	EA-ITP-G Project Guide #1	2:X:42-45
10. Select true statements related to the internal construction and electrical characteristics of nickel-cadmium battery. (1)	EA-ITP-G EA-ITP-GW	2:X:46,47 2:16, #22-#28

SPECIFIC OBJECTIVES

11. Explain the process of deep-cycling a nickel-cadmium battery. (1)	EA-ITP-G AC-65-9A	2:X:48 314,315
12. Select proper maintenance and safety procedures for servicing nickel-cadmium batteries. (1)	EA-ITP-G Technical Supplement #3 AC-65-9A ITP-G2	2:X:47,48 314-316 Program 7
13. Inspect and service a nickel-cadmium battery. (3)	EA-ITP-G AC-65-9A Project Guide #2	2:X:42-45 314-316

GENERAL
G105 AVIATION ELECTRICITY AND ELECTRONICS
INSPECT AND SERVICE BATTERIES
G105-E

INSTRUCTOR'S MODULE IMPLEMENTATION GUIDE

I. Order materials to supplement module--Videotapes:

A. Theory and Testing of Lead-Acid Batteries, ITP-G2, Program 6.

B. Theory and Testing of Nickel-Cadimum Batteries, ITP-G2, Program 7.

(NOTE: These videotapes are available from Aviation Maintenance Publishers, Inc., 1000 College View Drive, Riverton, Wyoming 82501.)

II. Implementation Suggestions

(NOTE: Have students read material related to specific objectives.)

Estimated Teaching Time		Theory	Lab
Objective 1	Explain the terms and definitions related to batteries using Technical Information Supplement #1. Have students read AC-65-9A, pages 306-316 as a homework assignment.		
Objective 2	Describe the characteristics of primary and secondary cells and discuss the main examples of each type. Have students read EA-ITP-G 2:X:40-42.		
Objective 3	Describe the internal construction and electrical characteristics of lead-acid batteries, including the composition of the plates and electrolyte, voltage per cell, and internal resistance. Have students read EA-ITP-G 2:X:40-42 and show Transparency Masters #1 and #2.		

INSTRUCTOR'S MODULE IMPLEMENTATION GUIDE

Estimated Teaching Time		Theory	Lab
Objective 4	Explain how specific gravity of the electrolyte can be used along with temperature to determine the state of charge of a lead-acid battery as well as the freezing point. Refer to charts A and B, Figure 10-9, EA-ITP-G 2:X:43, and show Transparency Masters #3 and #4. Describe the procedure for checking specific gravity with a hydrometer and cell voltages with a low-range voltmeter. Point out that Gill batteries have a specific gravity of 1.285.		
Objective 5	Explain battery ratings based on 5-hour, 20-minute, and 5-minute discharge rates. Have students refer to Figure 10-8, EA-ITP-G 2:X:43.		
Objective 6	Describe the inspection of a lead-acid battery and proper maintenance procedures. Have students read EA-ITP-G 2:X:44-45. Emphasize the use of bicarbonate of soda in solution for spilled acid and safety measures when mixing electrolyte. Have students complete EA-ITP-GW 2:15, #1-#21. Assist students as necessary.		
Objective 7	Explain the principles of constant-current and constant-voltage charging. Have students read EA-ITP-G 2:X:45-46. Briefly discuss charging of more than one battery according to AC 65-9A, page 313, Figure 8-110.		
Objective 8	Discuss safety measures related to servicing of lead-acid batteries. Have students read Technical Information Supplement #2 and EA-ITP-G 2:X:45-46. Show videotape ITP-G2, Program 6.		
Objective 9	Discuss the inspection and servicing of lead-acid batteries in a laboratory environment. Have students complete Project Guide #1.		

Estimated Teaching Time		Theory	Lab
Objective 10	Explain the construction and characteristics of a nickel-cadmium battery, and compare with the lead-acid battery. Show Transparency Master #5. Have students read EA-ITP-G 2:X:46-47, and complete EA-ITP-GW, 2:16:#22-#28. Assist as necessary.		
Objective 11	Explain the need for deep-cycling nickel-cadmium batteries to avoid thermal runaway and memory effect. Have students read EA-ITP-G 2:X:48.		
Objective 12	Describe proper maintenance procedures and safety measures for servicing nickel-cadmium batteries. Have students read EA-ITP-G 2:X:47-48 and Technical Information Supplement #3. Refer to the chart in AC-65-9A:316 and show videotape ITP-G2, Program 7.		
Objective 13	Discuss the inspection and servicing of nickel-cadmium batteries in a laboratory environment. Have students complete Project Guide #2.		

TECHNICAL INFORMATION SUPPLEMENT #1 - Terms and Definitions

A. Alkaline cell - Chemical cell using powdered manganese dioxide and zinc for its pole pieces and a water solution of potassium hydroxide for its electrolyte

B. Ampere-hour capacity - Amount of electrical energy a battery can produce relative to a given time span

(NOTE: Ampere-hour is dependent on the rate at which this energy is released.)

C. Battery - Connection or stacking of two or more cells to obtain more current or more potential difference or both than can be obtained from a single cell

D. Cable - In common usage, any heavy conductor

E. Carbon-zinc cell - Portable primary cell consisting of a carbon rod placed in a can made of zinc

(NOTE: The common flashlight battery is of this type.)

F. Charging current - Current passed through a secondary cell for the purpose of recharging it

G. Circuit - Complete path in which electrical current flows

(NOTE: A circuit must contain a source of electrical energy, a load to absorb this energy, and conductors to carry the electron flow.)

H. Constant-current charge - Method of charging a battery in which the voltage is adjusted as the charge progresses to keep the current constant

I. Constant-voltage charge - Method of charging a battery in which the voltage across the battery remains constant

(NOTE: The current will be high at the start of the charge, but tapers off to a low value as the charge progresses.)

J. Current - Progressive movement of electrons in a single direction along a conductor

(NOTE: Current flow is measured in amperes.)

K. Direct current (DC) - Flow of electrons in one direction throughout a circuit

L. Deep cycling - Treatment of nickel-cadmium batteries in which the battery is completely discharged, the cells shorted out and the battery is allowed to "rest." The battery is then recharged to 140 percent of its ampere-hour capacity

M. Dry charge battery - A battery sealed until it is ready to be put into service

(NOTE: This is a common way of shipping a lead-acid battery. Electrolyte is added and the battery given a freshening charge, making it ready for service.)

N. Electrolyte - Chemical liquid which will conduct electrical current by releasing ions to unite with ions on the electrodes

O. End voltage (end-of-life) - The voltage across a chemical cell when the cell should be discarded or recharged

(NOTE: The end voltage of a particular type of cell is usually defined by the manufacturer.)

P. Five-hour rating - Ampere hour rating of a battery which will discharge the battery in five hours

(NOTE: This is the most common rating for aircraft batteries.)

Q. Ground - Reference point for voltage measurement in an electrical circuit

R. Hydrometer - Device used to measure specific gravity of a liquid

(NOTE: A hydrometer consists of a weighted float with a long stem in the enlarged glass tube of a syringe. Liquid is pulled up into the tube and the float rides vertically on the surface. The amount the float is submerged is a function of the density of a liquid. The number on the float's stem opposite the liquid level is the specific gravity.)

S. Mercury cell - Primary cell using zinc for the negative electrode, mercuric oxide for the positive electrode, and potassium hydroxide as the electrolyte

T. Internal resistance - Resistance of the battery to the flow of current

(NOTE: Internal resistance causes a voltage drop proportional to the amount of current.)

U. Memory effect - Reduction in the service capacity of ni-cad cells which occurs when cells on standby service are regularly discharged to only a small fraction of their full service capacity

V. Negative terminal - Accepted name for the terminal of a battery or power source from which the electrons flow

W. Nickel-cadmium (ni-cad) battery - Battery made up of alkaline secondary cells. The positive plates are made of nickel hydroxide, the negative plates of cadmium hydroxide, and potassium hydroxide is used as the electrolyte

X. Positive terminal - Terminal of a battery or power source where electrons enter the source

Y. Primary cell - Electrical device which generates electron flow by converting some of its substance into ions with free electrons. Some of the material is destroyed in the process, therefore the cells are not rechargeable

Z. Secondary cell - Storage cell, or an electrical device in which electrical energy is converted into chemical energy and stored until needed, then converted back into electrical energy

AA. Service capacity - Measure of the amount of electrical energy that may be obtained from a chemical cell

(NOTE: Service capacity is measured under controlled conditions and given in ampere-hours.)

BB. Specific gravity - Ratio of the weight of a given volume of a material to the same volume of pure water

CC. Thermal runaway - Condition which exists in a nickel-cadmium battery when the cell resistances become unbalanced causing extreme temperature

(NOTE: The resistance of some cells decreases and allows the cells to take more current; this lowers their resistance further, allowing more current. This action continues until the battery is seriously damaged.)

(CAUTION: This may cause battery to explode.)

DD. Trickle charging - Constant-current charging method that keeps cells on standby service at full charge by passing a small current through them until they are put into service

EE. Unbalanced cell - Condition in a nickel-cadmium battery in which one cell has discharged more than the other cells in the battery

(NOTE: This is the initial step in a thermal problem.)

TECHNICAL INFORMATION SUPPLEMENT #2 - Lead-Acid Battery Safety Precautions

A. Avoid exposure to corrosive or toxic chemicals and explosive gases

B. Charge lead-acid batteries in an area isolated from nickel-cadmium batteries

(CAUTION: The electrolyte and fumes of lead-acid batteries are chemically opposite those of nickel-cadmium batteries, and tools used to service them should be considered contaminated.)

C. Provide sufficient ventilation for lead-acid batteries to eliminate explosive gases

D. Separate equipment and tools for lead-acid batteries from nickel-cadmium batteries

E. Use lifting devices to lift heavy batteries

F. Wear protective chemical safety goggles, rubber gloves, and aprons, and remove all metal jewelry

G. Make sure deluge showers and eyewash fountains or running tap water are available

H. Avoid smoking and open flames

I. Store tools and metal parts separate from batteries to prevent contamination

J. Consult manufacturer's specifications to prevent overcharging lead-acid batteries

K. Disconnect any hot and overcharged battery and allow to cool

L. Service a charged battery with distilled water only, never with electrolyte

(CAUTION: The chemical reaction of the mineral in tap water will shorten the longevity of the battery. When mixing electrolytes always pour the acid into the water.)

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TECHNICAL INFORMATION SUPPLEMENT #3 - Nickel-Cadmium Battery Safety Precautions

A. Use only insulated tools to service nickel-cadmium batteries

(CAUTION: Short-circuiting the intercell connectors can produce a tremendous surge of power, resulting in severe arcing and possible injury to personnel, as well as battery damage.)

B. Never wear metal jewelry when performing aicraft maintenance

(CAUTION: If these items contact intercell connectors of opposite polarity, they may fuse themselves to the connectors and cause severe burns.)

C. Separate nickel-cadmium batteries, tools, and facilities from lead-acid batteries

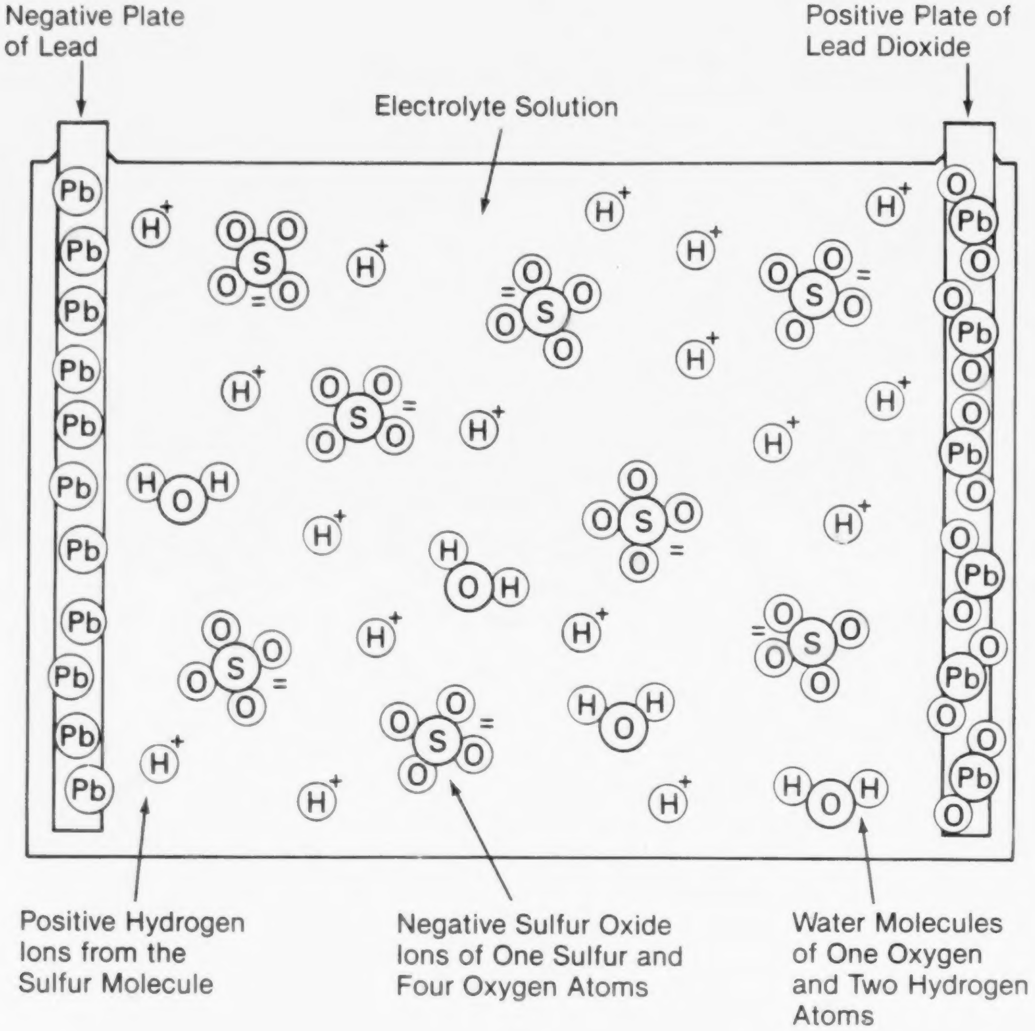
(CAUTION: The electrolyte and fumes of lead-acid batteries are chemically opposite those of nickel-cadmium batteries, and tools used to service them should be considered contaminated.)

D. Avoid prolonged high-discharge rates

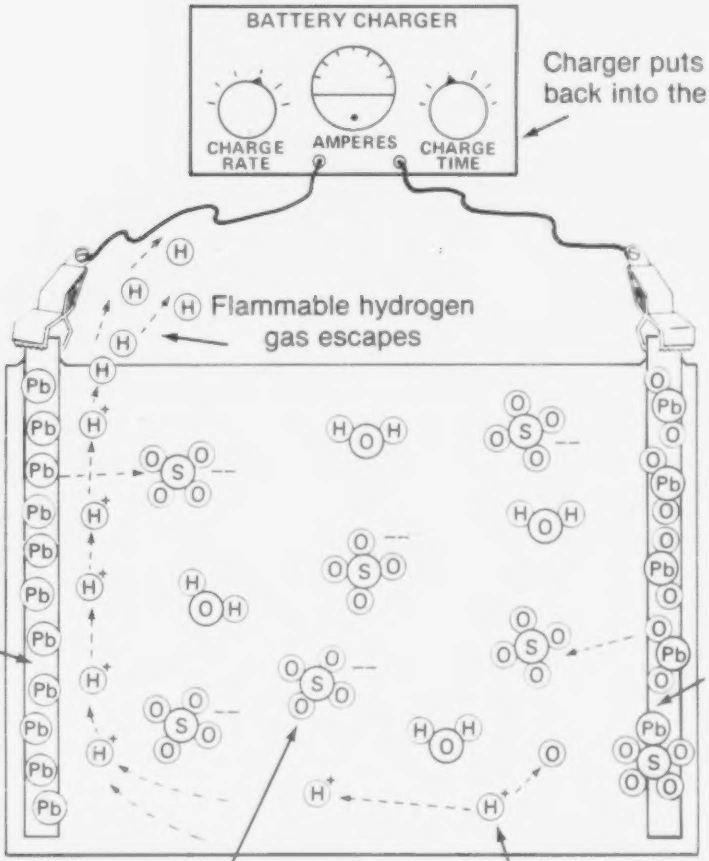
(CAUTION: A nickel-cadmium battery's internal resistance varies inversely with temperature. A significant rise in internal temperature can lead to thermal runaway and possible explosion of the battery.)

E. Connect grounding straps before disconnecting dummy loads to avoid sparking

Lead-Acid Battery Chemical Composition


Negative Plate of Lead
Positive Plate of Lead Dioxide
Electrolyte Solution
Pb
H+
O
S
=
H O H
Positive Hydrogen Ions from the Sulfur Molecule
Negative Sulfur Oxide Ions of One Sulfur and Four Oxygen Atoms
Water Molecules of One Oxygen and Two Hydrogen Atoms

Chemical Activity During Charging



Charger puts energy back into the battery

Flammable hydrogen gas escapes

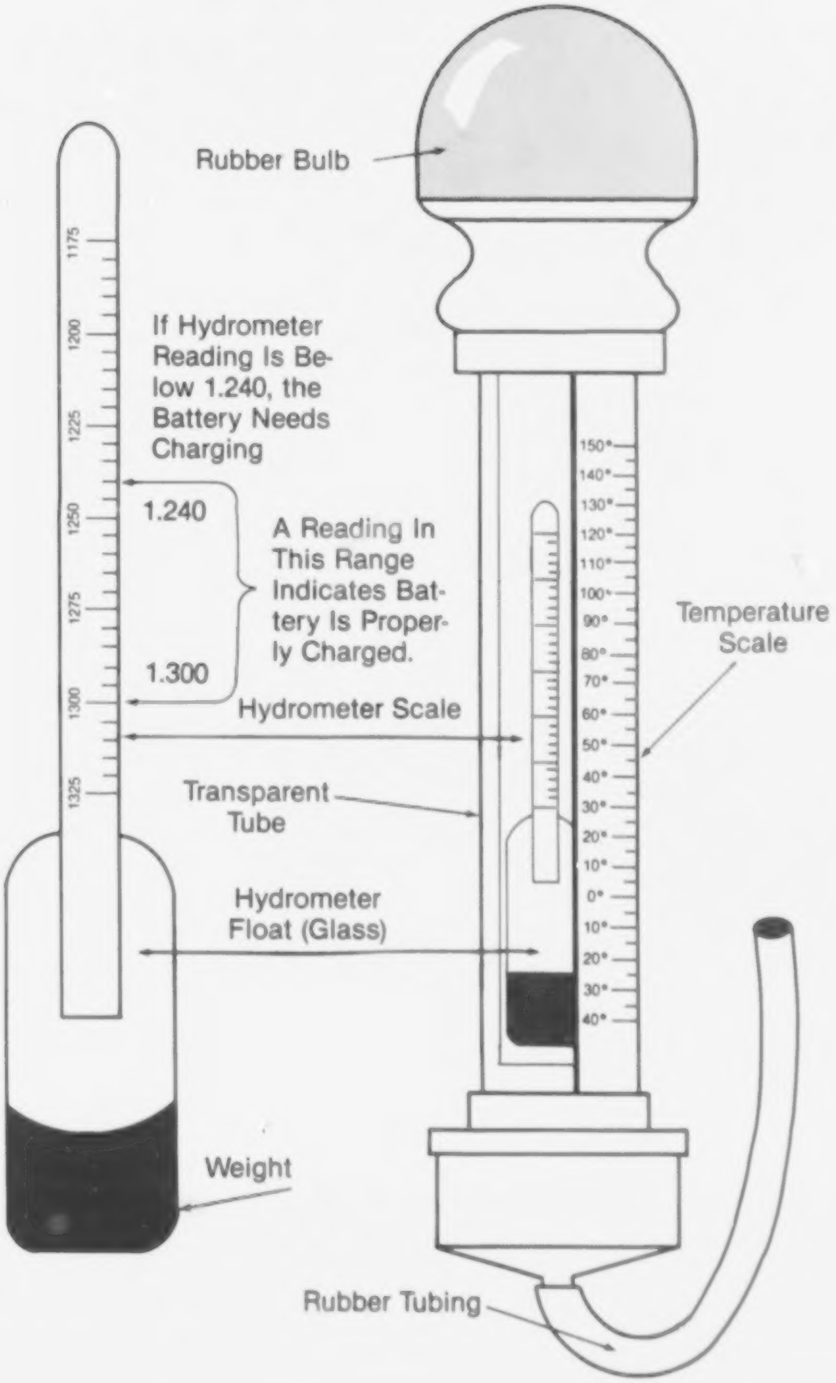
Negative plate is changed back to lead as the sulfur-oxide ions depart

Positive plate is changed back to lead-dioxide as the sulfur-oxide ions depart and oxygen atoms arrive

Electrolyte becomes stronger and heavier as more sulfur-oxide ions enter solution

Water molecules are separated; oxygen atoms go to the positive plate; hydrogen atoms go to the negative plate; water is used and must be replaced

The Hydrometer


Rubber Bulb
1175
1200
1225
1250
1275
1300
1325
If Hydrometer Reading Is Below 1.240, the Battery Needs Charging
1.240
1.300
A Reading In This Range Indicates Battery Is Properly Charged.
Hydrometer Scale
Transparent Tube
Hydrometer Float (Glass)
Weight
150°
140°
130°
120°
110°
100°
90°
80°
70°
60°
50°
40°
30°
20°
10°
0°
10°
20°
30°
40°
Temperature Scale
Rubber Tubing

Specific Gravity Correction Chart

(A) Electrolyte Temperature		Correction points Add or Subtract
°C	°F	
60	140	+24
55	130	+20
49	120	+16
43	110	+12
38	100	+ 8
33	90	+ 4
27	80	0
23	70	− 4
15	60	− 8
10	50	−12
5	40	−16
− 2	30	−20
− 7	20	−24
−13	10	−28
−18	0	−32
−23	−10	−36
−28	−20	−40
−35	−30	−44

(B) Specific Gravity	Freezing Point	
	°C	°F
1.300	−70	−90
1.275	−62	−80
1.250	−52	−62
1.225	−37	−35
1.200	−26	−16
1.175	−20	− 4
1.150	−15	+ 5
1.125	−10	+13
1.100	− 8	+19

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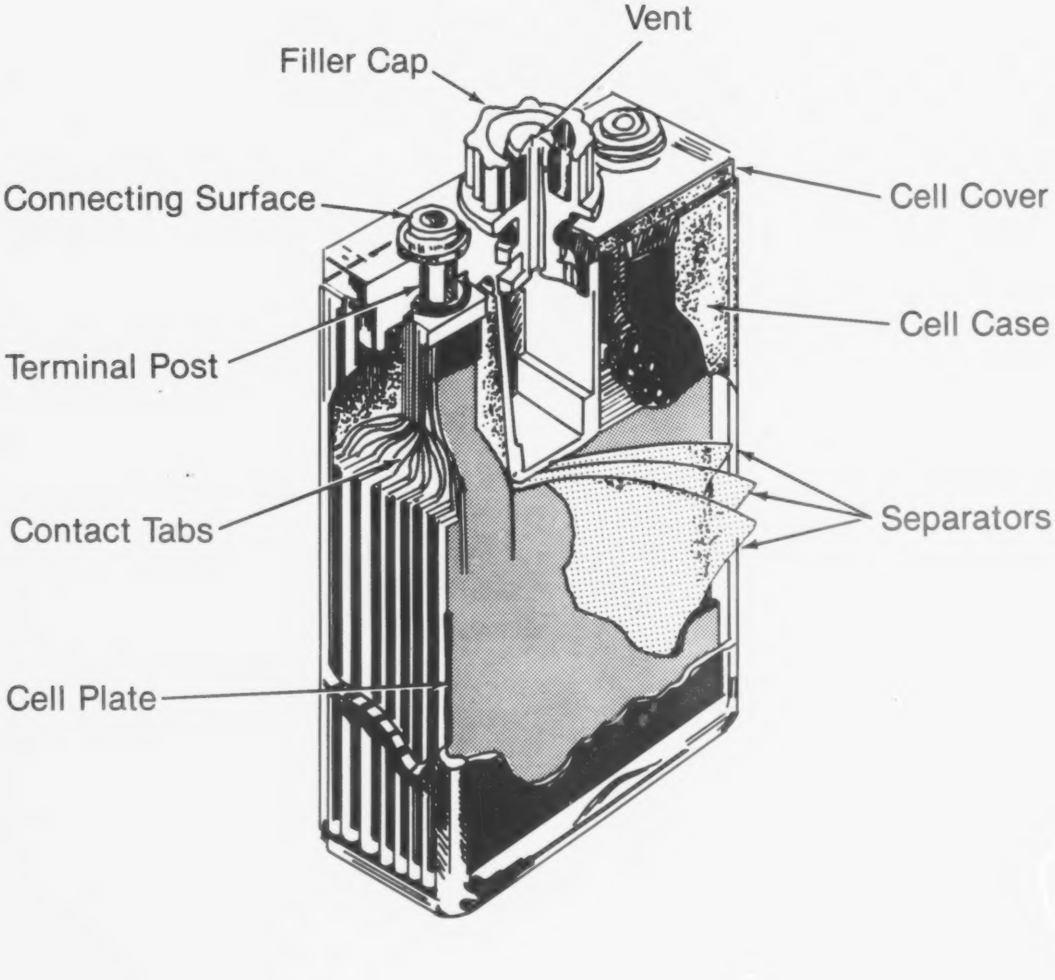
Nickel-Cadmium Battery Cell Construction


Vent
Filler Cap
Connecting Surface
Cell Cover
Cell Case
Terminal Post
Contact Tabs
Separators
Cell Plate

Typical Nickel-Cadmium Cell

Adapted with permission of Dale Crane and Aviation Maintenance Foundation, Inc., 1984.

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INSPECT AND SERVICE AIRCRAFT BATTERIES
G105-E

PROJECT GUIDE #1--Inspect And Service a Lead-Acid Battery

PURPOSE: A properly serviced and maintained battery ensures reliable starting, auxiliary, and emergency power for the aircraft. This project guide will assist you in inspecting and servicing a lead-acid battery, testing electrolyte specific gravity, and in the operation of the constant-current battery charger.

REFERENCE MANUALS:

A. EA-ITP-G

B. AC 43.13-1A and 2A: Chapter 9: Section 8

C. Manufacturer's service manual

EQUIPMENT AND TOOLS NEEDED:

A. Constant-current battery charger

B. 12 V lead-acid aircraft battery

C. Rubber suction ball

D. Hydrometer

E. Thermometer

SUPPLIES AND MATERIALS:

A. Rubber gloves

B. Safety goggles

C. Rubber aprons

D. Face shields

E. Dilute solution of baking soda and water

F. Water source

G. Shop towel

H. Brush

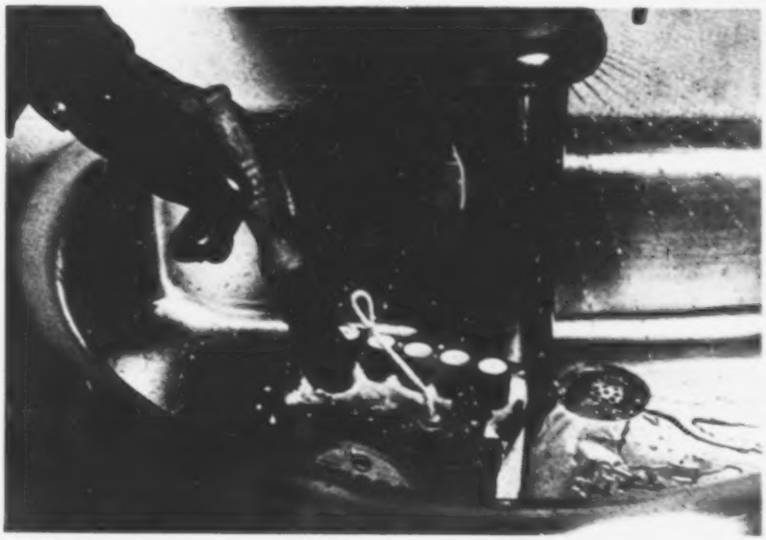
PROCEDURE:

(NOTE: Before performing this project, refer to the manufacturer's service manual for the specific battery.)

A. Check general condition of battery case and posts for cleanliness or corrosion

B. Clean battery with baking soda solution, if necessary (Figure 1)

FIGURE 1



(CAUTION: Do not allow any solution to contaminate the electrolyte inside the battery.)

C. Remove and check each cell cap for proper operation (Figure 2)

FIGURE 2

(NOTE: If a spill-proof filler plug is used, the cap should rattle.)

D. Record overall condition of the battery

1. Record the level of electrolyte in each cell (Figure 3)

a. Cell 1 ______

b. Cell 2 ______

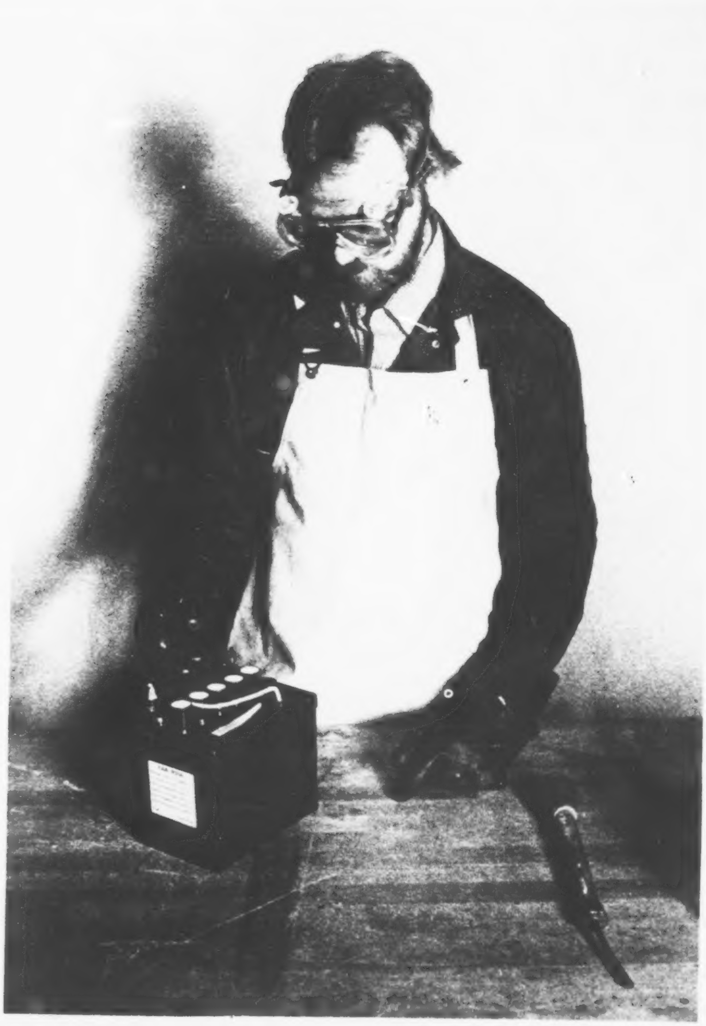
c. Cell 3 ______

d. Cell 4 ______

e. Cell 5 ______

f. Cell 6 ______

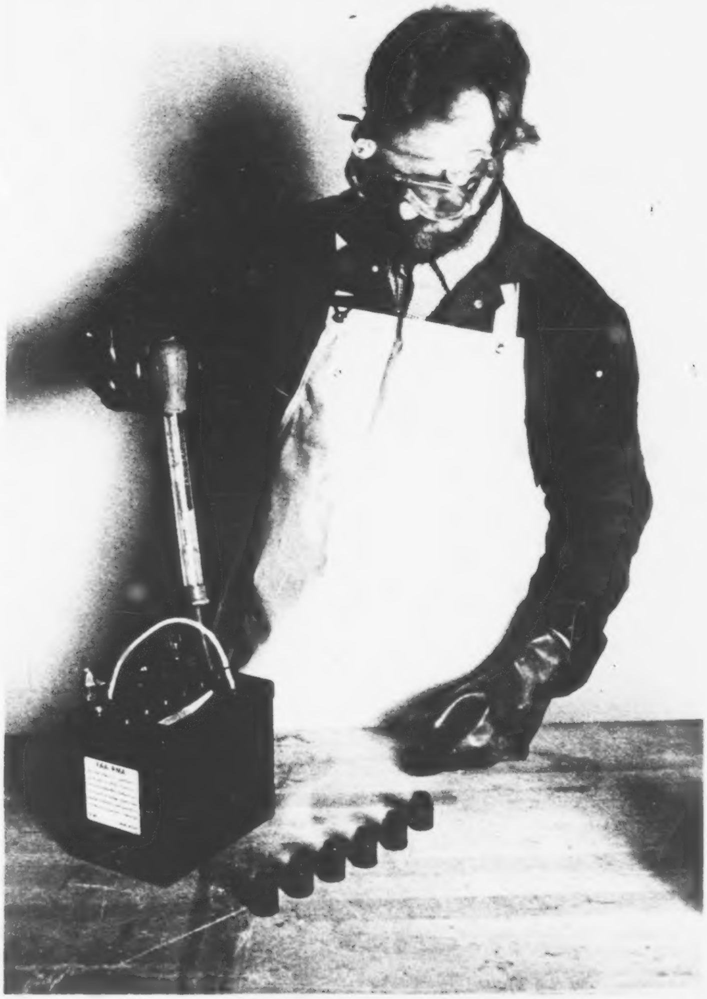
FIGURE 3



2. Record specific gravity of individual cells (Figure 4)

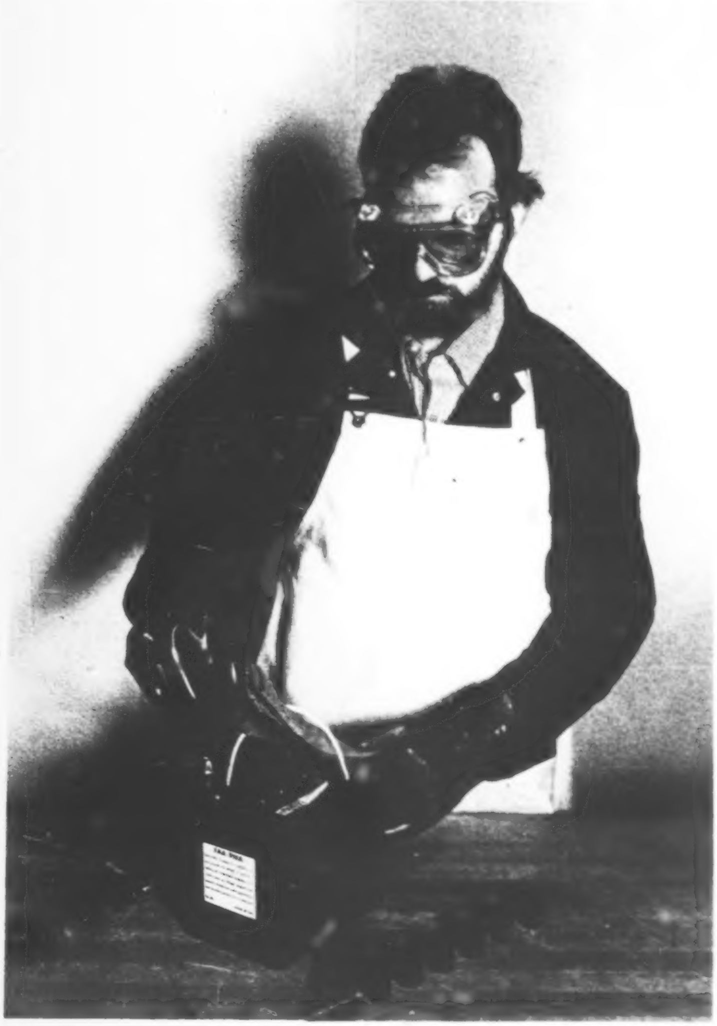
a. Cell 1 ______
d. Cell 4 ______
b. Cell 2 ______
e. Cell 5 ______
c. Cell 3 ______
f. Cell 6 ______

FIGURE 4



E. Place a shop towel over the open cells (Figure 5)

FIGURE 5



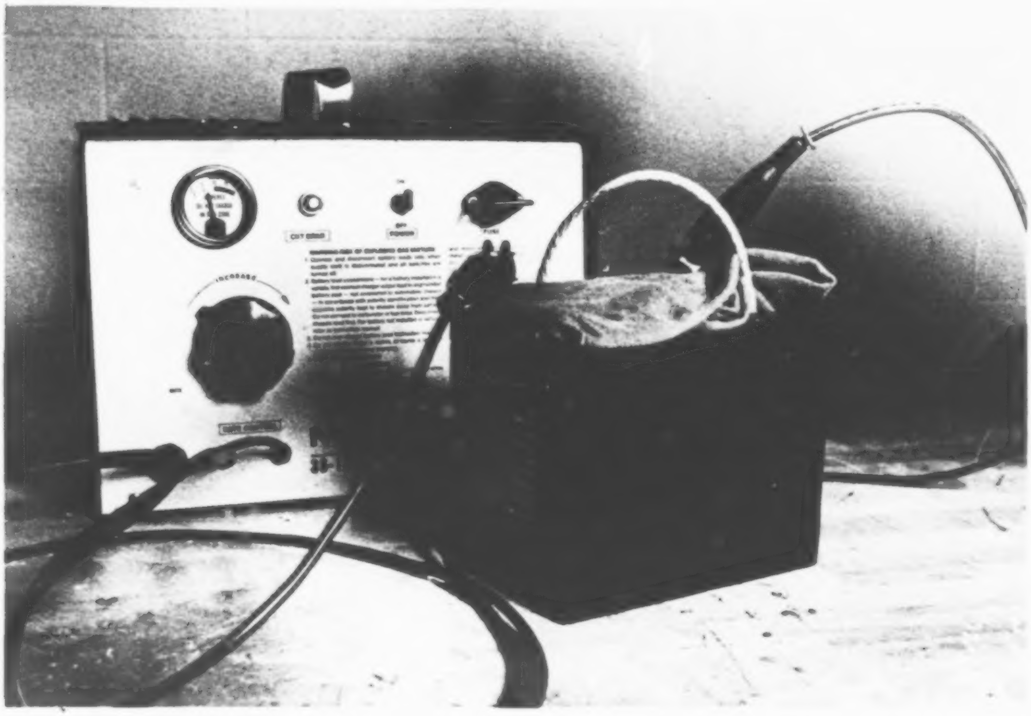
(NOTE: Shop towel prevents splashing of electrolyte during gasing while battery is being charged.)

F. Attach charger and charge battery at 7 percent of amp-hour rating (Figure 6)

(CAUTION: If battery is very low on charge, avoid heating battery beyond 125° F.)

(NOTE: Use thermometer to check battery temperature. If thermometer is not available, use the "rule of thumb" that if battery is warm to the touch, reduce the rate of charge by half.)

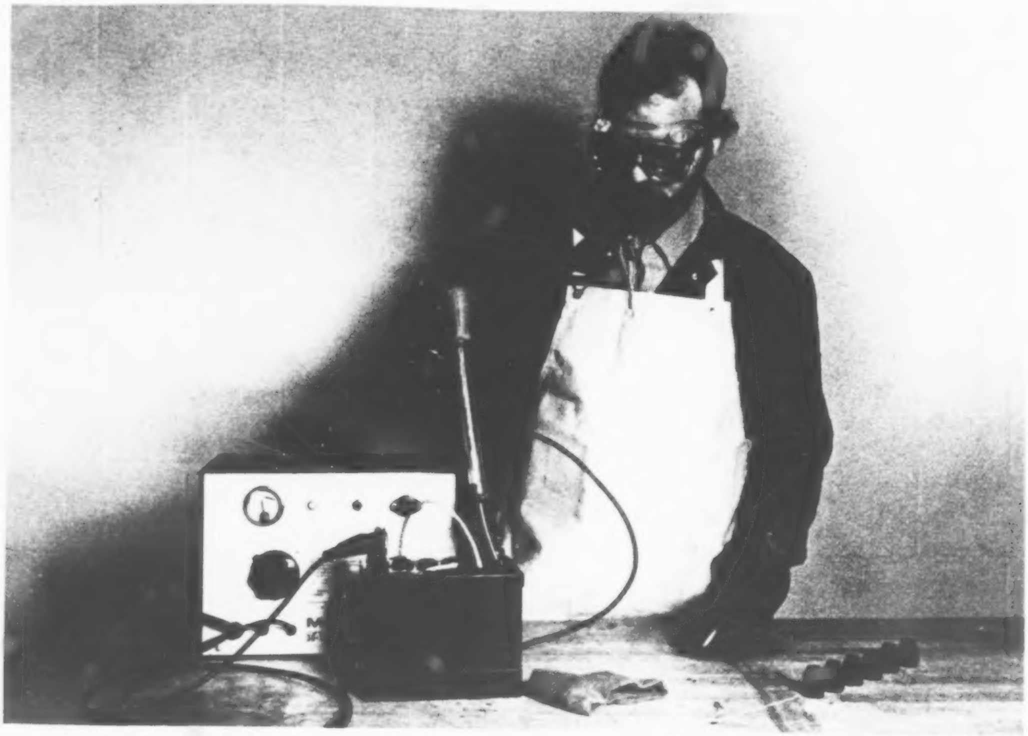
FIGURE 6



G. Check battery at regular intervals with hydrometer (Figure 7)

		Reading 1	Reading 2	Reading 3
a.	Cell 1	________	________	________
b.	Cell 2	________	________	________
c.	Cell 3	________	________	________
d.	Cell 4	________	________	________
e.	Cell 5	________	________	________
f.	Cell 6	________	________	________

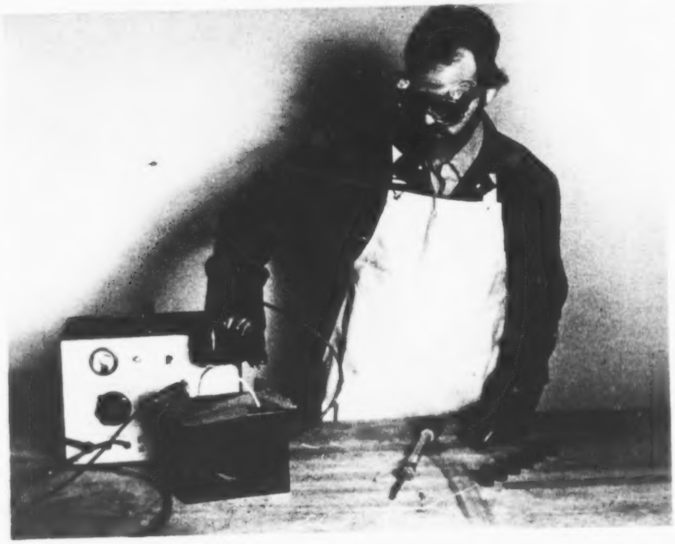
FIGURE 7



(NOTE: Battery is considered fully charged when three consecutive hydrometer readings taken 30 minutes apart show no change in specific gravity and all cells are gasing freely.)

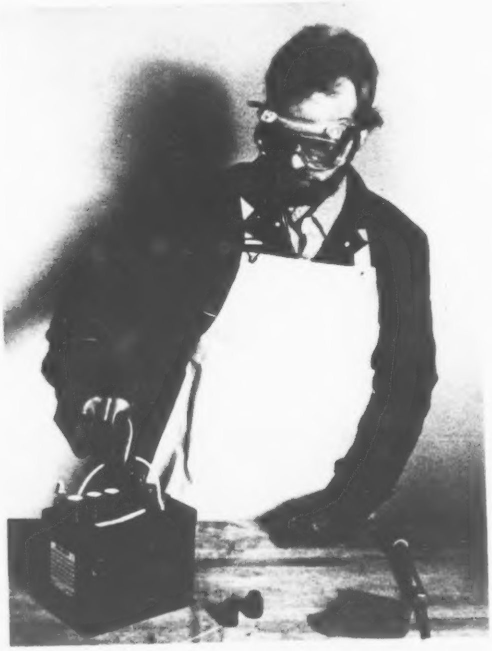
H. When battery is charged, disconnect charger (Figure 8)

FIGURE 8



I. Replace cell caps and clean up any spilled acid with baking soda solution (Figure 9)

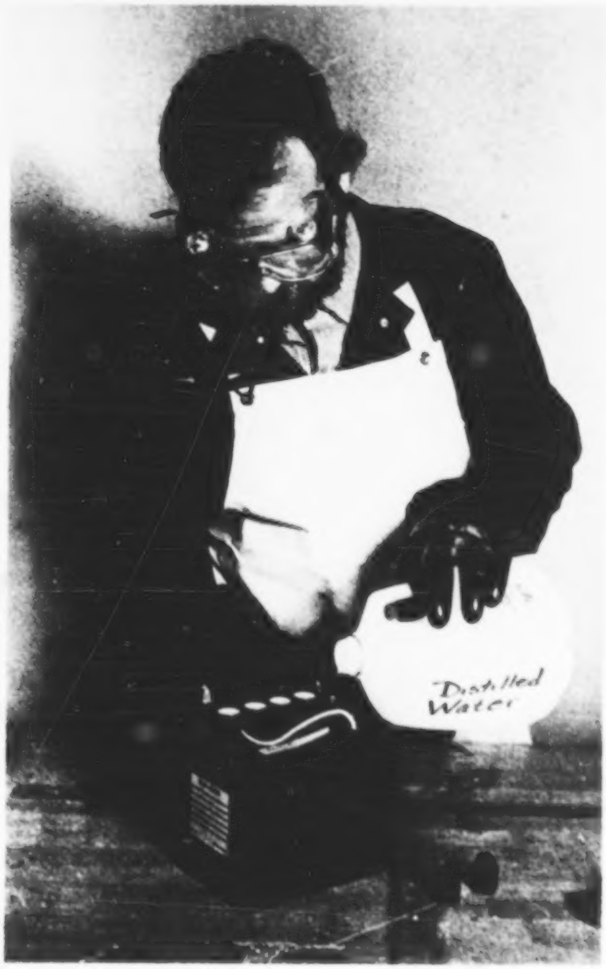
FIGURE 9



J. After 3 hours adjust electrolyte to proper level using distilled water (Figure 10)

(CAUTION: If battery is to be exposed to freezing temperatures it should be in use to ensure that the distilled water has become part of electrolyte solution.)

FIGURE 10



K. Have instructor evaluate your work

L. Return equipment and materials to instructor

PROJECT GUIDE #2--Inspect And Service a Nickel-Cadmium Battery

PURPOSE: A properly serviced and maintained battery ensures reliable starting, auxiliary, and emergency power for the aircraft. This project guide will assist you in inspecting and servicing a nickel-cadmium battery, checking individual cell voltages, and complete deep cycling.

REFERENCE MANUALS:

A. AC 43.13 1A and 2A - Chapter 9, Section 8

B. Manufacturer's Service Manual

EQUIPMENT AND TOOLS NEEDED:

A. Constant-current battery charger

B. Voltmeter

C. Allen wrenches

D. Open end wrenches

E. Cell puller

F. Ni-cad battery

G. Shorting straps

H. Turque wrench

I. Suction ball

SUPPLIES AND MATERIALS:

A. Distilled water

B. Boric acid solution

C. Safety goggles

D. Rubber apron

E. Face shield

F. Soft brush

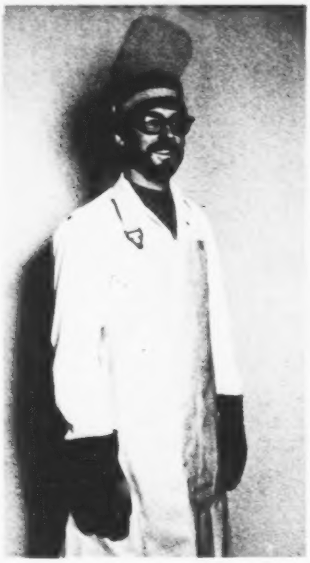
G. Rubber gloves

PROCEDURE:

(NOTE: Prior to performing this project refer to the manufacturer's service manual for the specific battery.)

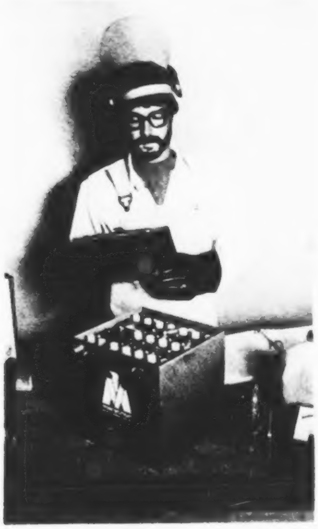
A. Put on protective clothing (Figure 11)

FIGURE 11



B. Remove the battery cover (Figure 12)

FIGURE 12



PROJECT GUIDE #2

C. Record condition of the box, cells, and hardware

1. Box--____

____

2. Cells--____

____

3. Hardware--____

____

D. Check and record individual cell voltages (see Figure 13)

(NOTE: Any cell that has more than a 0.2 V difference from the other cells should be noted and watched closely during the discharge to prevent possible damage from overheating. Fully charged single cell voltage is 1.55 V to 1.75 V for SAFT and Marathon; 1.55 V to 1.80 V for G.E.)

a. Cell 1 ______

b. Cell 2 ______

c. Cell 3 ______

d. Cell 4 ______

e. Cell 5 ______

f. Cell 6 ______

g. Cell 7 ______

h. Cell 8 ______

i. Cell 9 ______

j. Cell 10 ______

k. Cell 11 ______

l. Cell 12 ______

m. Cell 13 ______

n. Cell 14 ______

o. Cell 15 ______

p. Cell 16 ______

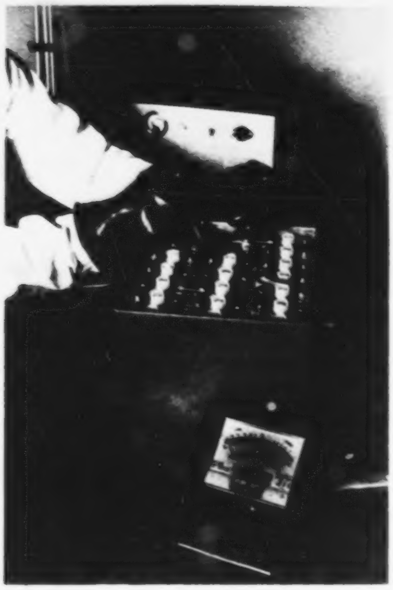
q. Cell 17 ______

r. Cell 18 ______

s. Cell 19 ______

t. Cell 20 ______

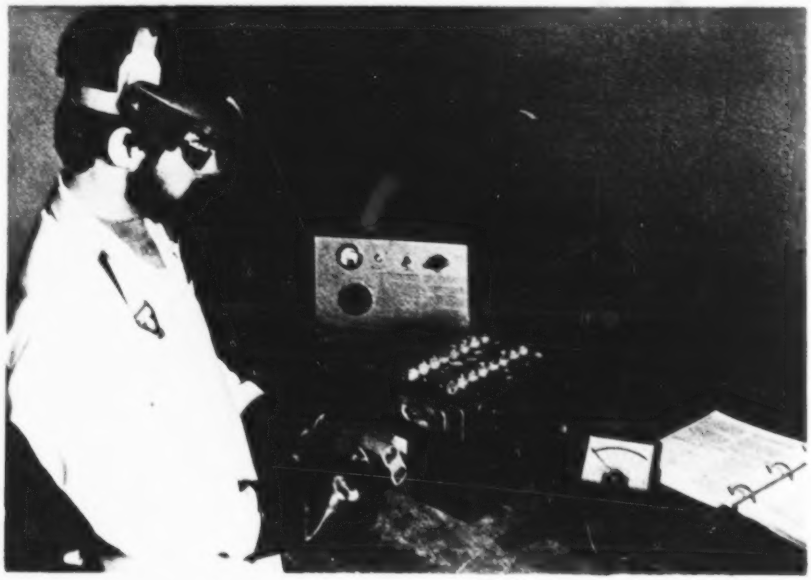
FIGURE 13



E. Place a test load on the battery to draw it down to 18 V; record the time the load was installed below (Figure 14)

(NOTE: This process will take approximately 2 hours.)

FIGURE 14



Time load installed ______________

F. Install a dummy load for approximately 8 hours to discharge to a cell voltage of 0.5 V maximum; record the time the load was installed below

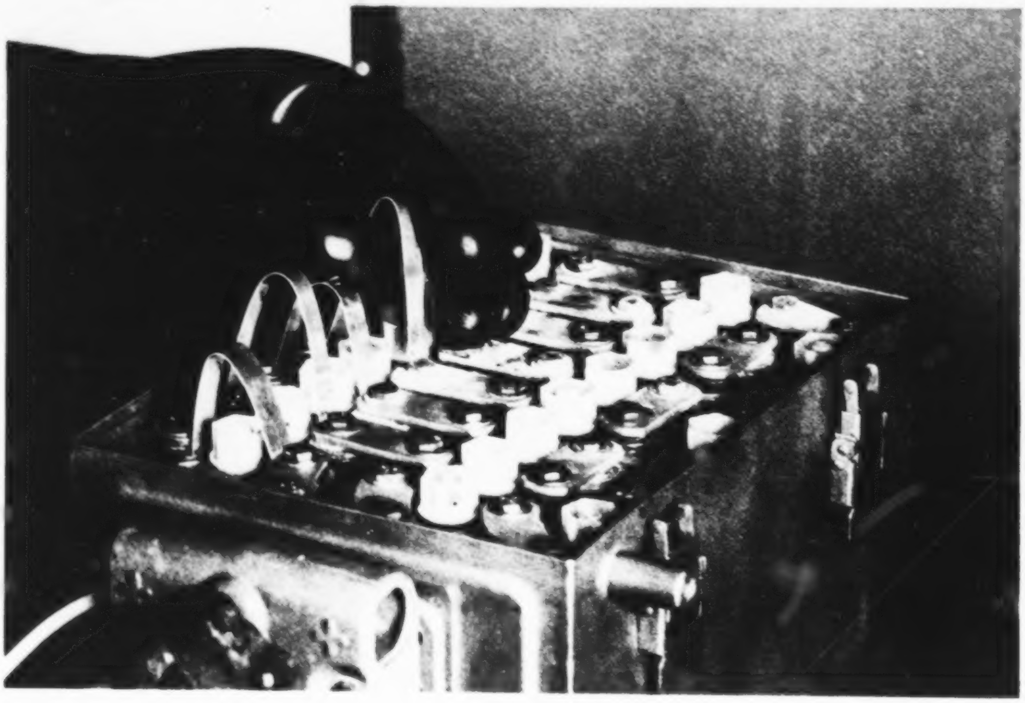
Time load installed ______________

G. Install shorting straps; record the time the straps were installed below (Figure 15)

(NOTE: Leave the straps on for 3 hours [minimum] or until the cells are at room temperature. This procedure is performed while the dummy load is still attached to prevent sparking at the cell post.)

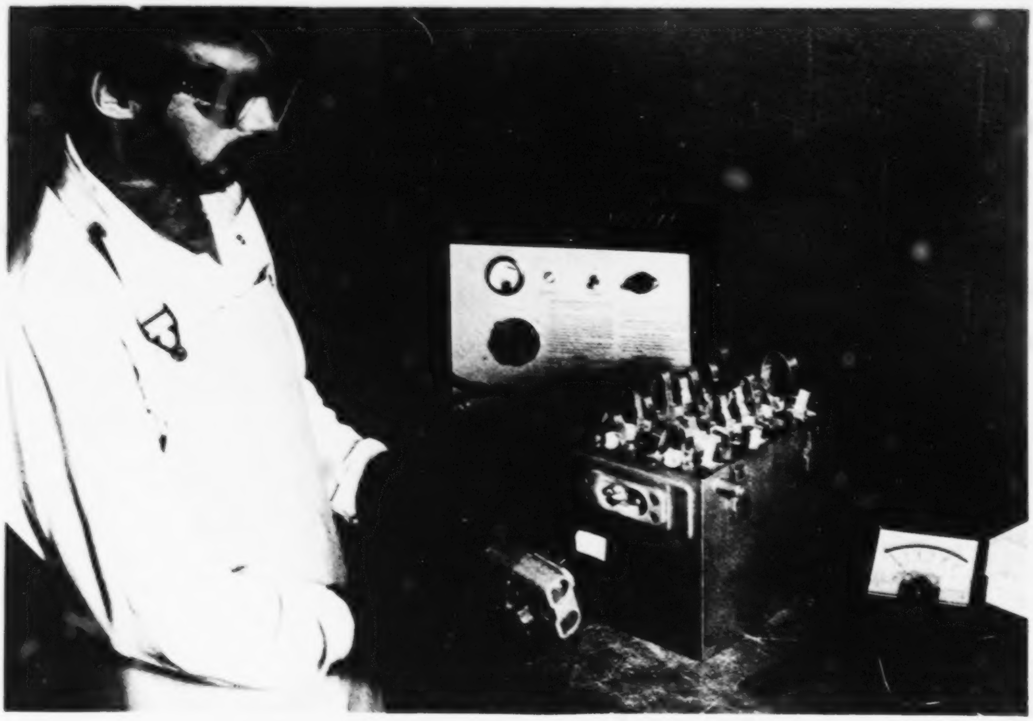
Time straps installed ______________

FIGURE 15



H. Remove the dummy load (Figure 16)

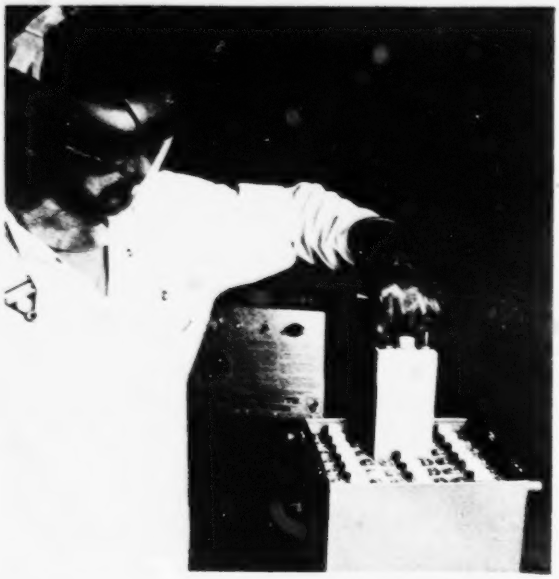
FIGURE 16



I. Draw a diagram of the cell layout in the battery box and the layout or pattern of the attaching hardware below

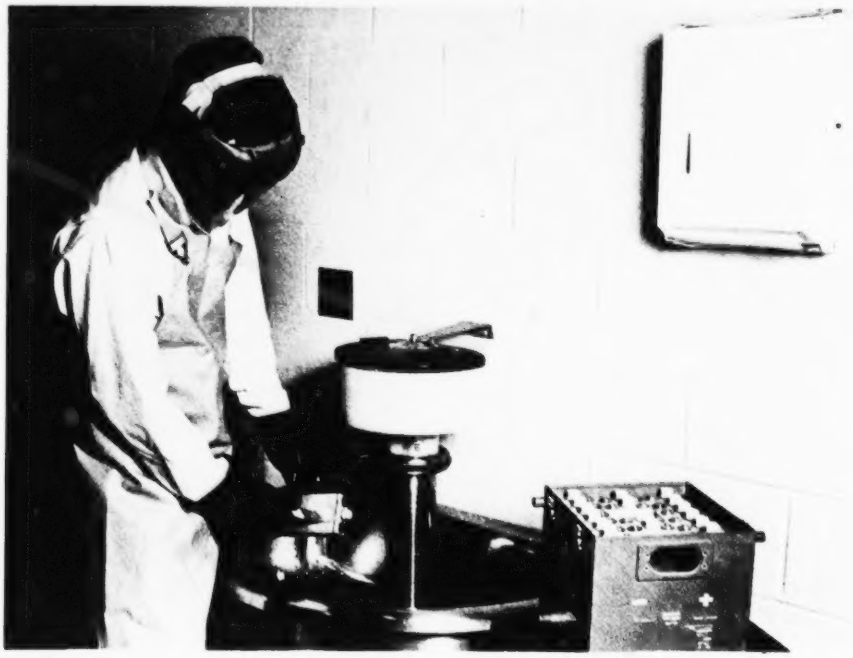
J. Remove cells and all hardware from battery box (Figure 17)

FIGURE 17



K. Using a nylon or other nonmetallic brush, soap, and water, clean all cells, hardware, and battery box; air dry (Figure 18)

FIGURE 18



L. Inspect all cells, hardware, and battery box (Figure 19)

FIGURE 19

M. Place battery cells back in battery box (Figure 20)

(NOTE: Put cells in battery box according to diagram in step I.)

FIGURE 20

N. Recheck and record individual cell voltages (Figure 21)

(NOTE: If they are not at zero volts, re-install the shorting straps for 3 hours or until all cells are at zero volts.)

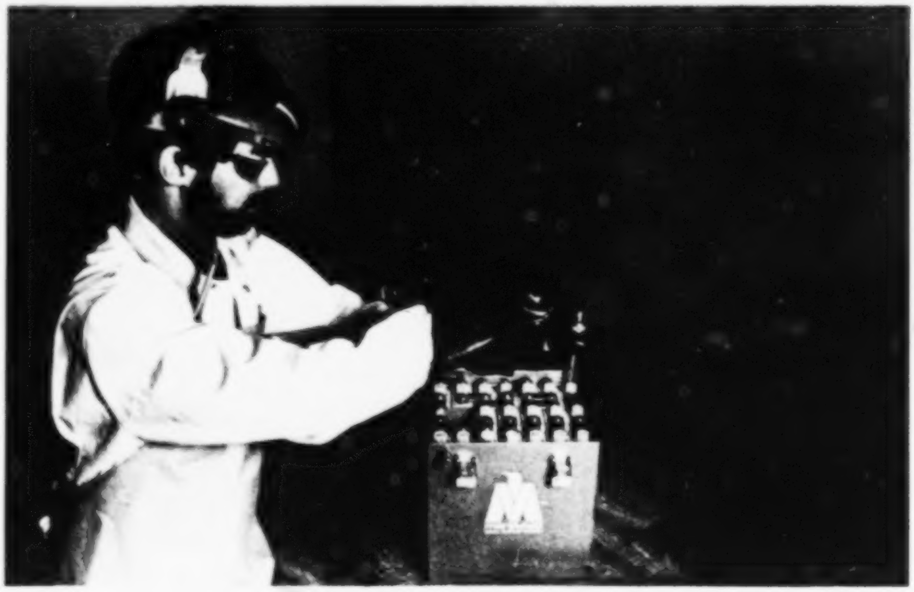
a. Cell 1 ______
b. Cell 2 ______
c. Cell 3 ______
d. Cell 4 ______
e. Cell 5 ______
f. Cell 6 ______
g. Cell 7 ______
h. Cell 8 ______
i. Cell 9 ______
j. Cell 10 ______
k. Cell 11 ______
l. Cell 12 ______
m. Cell 13 ______
n. Cell 14 ______
o. Cell 15 ______
p. Cell 16 ______
q. Cell 17 ______
r. Cell 18 ______
s. Cell 19 ______
t. Cell 20 ______

FIGURE 21

O. Refer to the drawing in step I; when all cells are at zero volts, reinstall cells and hardware into the battery box

P. Torque intercell connectors to manufacturer's specifications (Figure 22)

FIGURE 22



Q. Determine the charging rate at 10 percent of the amp-hour rate of the battery for a time equal to 140 percent of the amp-hour rate of the battery

EXAMPLE: For a 35 amp-hour battery

Charge for 10 hours at 3.5 A = 100 percent
Charge for 4 hours at 3.5 A = 40 percent

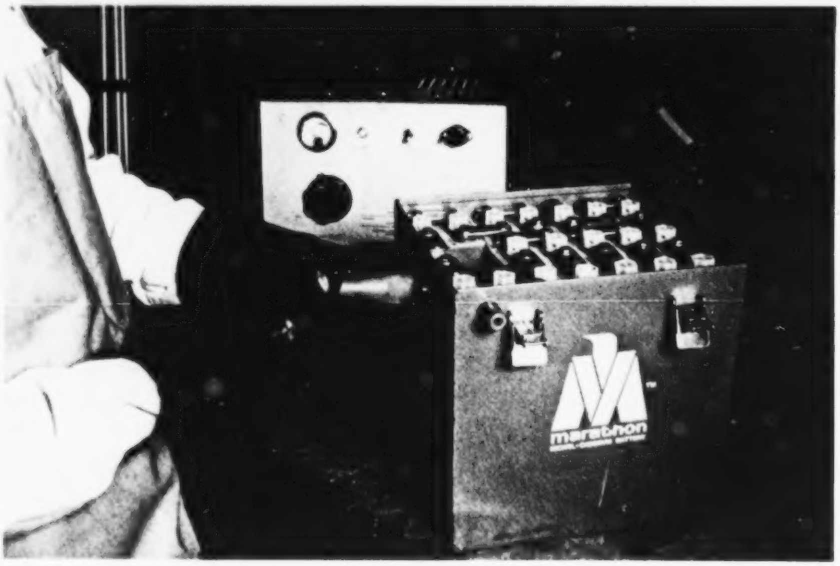
Total charge is 14 hours at 3.5 A = 140 percent

1. Charging rate for this battery ______________________________
2. Charging time for this battery ______________________________

R. Turn charger off

S. Attach positive lead of charger to positive post of battery and negative lead to negative post (Figure 23)

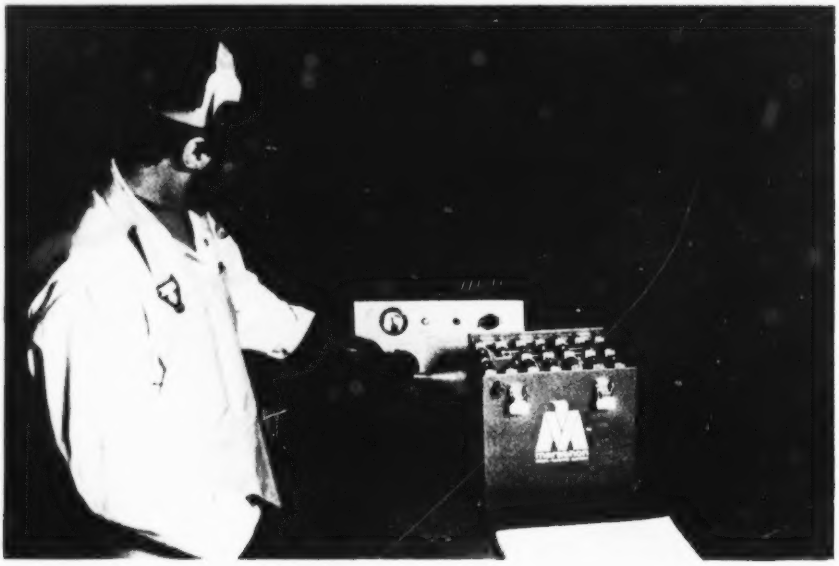
FIGURE 23



T. Turn on charger and adjust current flow to proper rate; record time charging was started below (Figure 24)

Time charging started ________________

FIGURE 24



PROJECT GUIDE #2

U. Check and record individual cell voltages every 15 minutes maximum for the first hour

(NOTE: If a cell voltage comes up to 0.5 V above the average of the other cells, mark the cell and watch it. If the imbalance continues for 30 minutes or until the battery voltage comes up to the specifications of that battery [approximately 1.50 V per cell times the number of cells] or excessive temperature of the cells is noticed, discontinue the charging cycle. Go to step U. If cell voltages balance to within 0.2 V, go to step V.)

	READING #1	READING #2	READING #3	READING #4
a. Cell 1	________	________	________	________
b. Cell 2	________	________	________	________
c. Cell 3	________	________	________	________
d. Cell 4	________	________	________	________
e. Cell 5	________	________	________	________
f. Cell 6	________	________	________	________
g. Cell 7	________	________	________	________
h. Cell 8	________	________	________	________
i. Cell 9	________	________	________	________
j. Cell 10	________	________	________	________
k. Cell 11	________	________	________	________
l. Cell 12	________	________	________	________
m. Cell 13	________	________	________	________
n. Cell 14	________	________	________	________
o. Cell 15	________	________	________	________
p. Cell 16	________	________	________	________
q. Cell 17	________	________	________	________
r. Cell 18	________	________	________	________
s. Cell 19	________	________	________	________
t. Cell 20	________	________	________	________

V. Discontinue charging cycle

(NOTE: Follow steps D-H and start the charging cycle again. If the imbalance occurs again, discharge the battery and replace the faulty cell.)

W. Check the battery cell voltage every 30 minutes maximum for the remainder of the charging cycle

(NOTE: Cell voltage is 1.55 V to 1.75 V for SAFT and Marathon, 1.55 V to 1.80 V for G.E. at a temperature between 70°F and 80°F.)

X. Allow the battery to rest for 2 hours; record the time the rest cycle starts below

Time rest cycle started ______________

Y. Check the electrolyte level using a glass or polystyrene tube (Figure 25)

(NOTE: Refer to manufacturer's recommendations.)

FIGURE 25

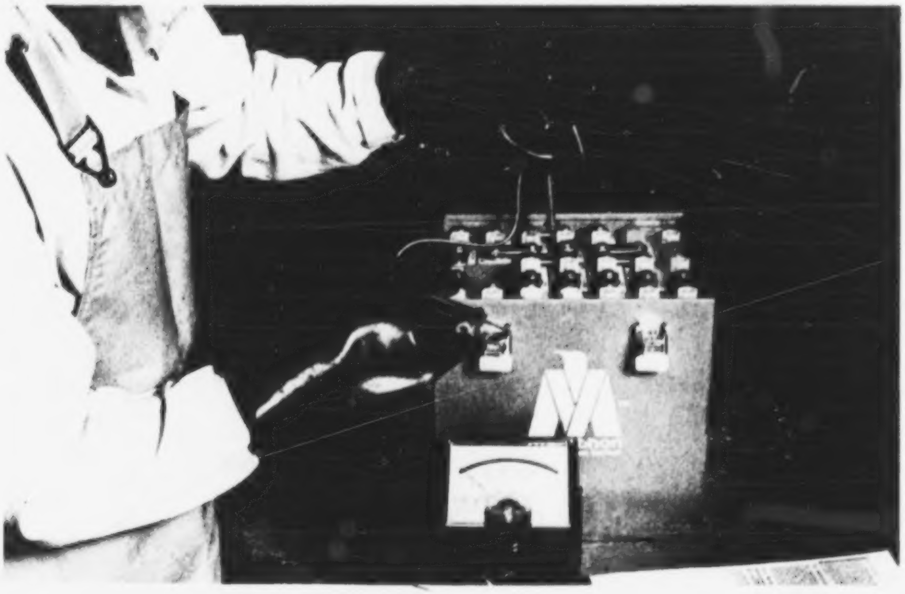
Z. Recheck the torque on the intercell connectors

AA. Using an ammeter, check for leakage to the battery box by measuring and recording the current flow between the battery positive post and the battery box; record the amount of leakage below (Figure 26)

(NOTE: Leakage of 100 mA or more is excessive.)

Leakage is ______________ mA

FIGURE 26



BB. Make entry in aircraft battery warranty book

CC. Have instructor evaluate your work

DD. Return equipment and materials to instructor

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THEORY TEST

1. Match terms related to aircraft batteries to their correct definitions. Write the correct numbers in the blanks.

____a. Electrical device which generates electron flow by converting some of its substance into ions with free electrons. Some of the material is destroyed in the process, therefore the cells are not rechargeable

____b. Terminal of a battery or power source where electrons enter the source

____c. Battery made up of alkaline secondary cells. The positive plates are made of nickel hydroxide, the negative plates of cadmium hydroxide, and potassium hydroxide is used as the electrolyte

____d. Accepted name for the terminal of a battery or power source from which the electrons flow

____e. Primary cell using zinc for the negative electrode, mercuric oxide for the positive electrode, and potassium hydroxide as the electrolyte

____f. Storage cell, or an electrical device in which electrical energy is converted into chemical energy and stored until needed, then converted back into electrical energy

1. Secondary cell
2. Primary cell
3. Positive terminal
4. Negative terminal
5. Nickel-cadmium (ni-cad) battery
6. Mercury cell

_____g. Reduction in the service capacity of ni-cad cells which occurs when cells on standby service are regularly discharged to only a small fraction of their full service capacity

_____h. Ratio of the weight of a given volume of a material to the same volume of pure water

_____i. Measure of the amount of electrical energy that may be obtained from a chemical cell

_____j. Constant-current charging method that keeps cells on standby service at full charge by passing a small current through them until they are put into service

_____k. Condition which exists in a nickel-cadmium battery when the cell resistances become unbalanced causing extreme temperature

_____l. Method of charging a battery in which the voltage is adjusted as the charge progresses to keep the current constant

_____m. Method of charging a battery in which the voltage across the battery remains constant

_____n. Current passed through a secondary cell for the purpose of recharging it

7. Constant-current charge
8. Constant-voltage charge
9. Service capacity
10. Trickle charging
11. Thermal runaway
12. Specific gravity
13. Charging current
14. Memory effect

_____o. In common usage, any heavy conductor

_____p. Portable primary cell consisting of a carbon rod placed in a can made of zinc

_____q. Connection or stacking of two or more cells to obtain more current or more potential difference or both than can be obtained from a single cell

_____r. Chemical cell using powdered manganese dioxide and zinc for its pole pieces and a water solution of potassium hydroxide for its electrolyte

_____s. Progressive movement of electrons in a single direction along a conductor

_____t. Complete path in which electrical current flows

_____u. A reference point for voltage measurement in an electrical circuit

_____v. Flow of electrons in one direction throughout a circuit

_____w. Device used to measure specific gravity of a liquid

15. Battery
16. Alkaline cell
17. Circuit
18. Carbon-zinc cell
19. Current
20. Cable
21. Hydrometer
22. Ground
23. Direct current

_____x. Voltage across a chemical cell when the cell should be discarded or recharged

_____y. A battery sealed until it is ready to be put into service.

_____z. A chemical liquid which will conduct electrical current by releasing ions to unite with ions on the electrodes

_____aa. Amount of electrical energy a battery can produce relative to a given time span

_____bb. Resistance of the battery to the flow of current

_____cc. The ampere hour rating of a battery which will discharge the battery in five hours

_____dd. Treatment of nickel-cadmium batteries in which the battery is completely discharged, the cells shorted out and the battery is allowed to "rest". The battery is then recharged to 140 percent of its ampere-hour capacity

_____ee. Condition in a nickel-cadmium battery in which one cell has discharged more than the other cells in the battery

24. Electrolyte
25. End voltage
26. Dry charge battery
27. Ampere-hour capacity
28. Internal resistance
29. Five hour rating
30. Deep cycling
31. Unbalanced cell

THEORY TEST

2. Match common types of batteries to their general classifications. Write the correct numbers in the blanks. A letter may have more than one correct answer.

_____a. Primary cell

_____b. Secondary cell

1. Lead-acid battery
2. Carbon-zinc battery
3. Mercury battery
4. Nickel-cadmium battery
5. Alkaline battery (Zinc rod, carbon container, steel case, moist potassium hydroxide electrolyte, and insulating disc)

3. Select true statements related to the internal construction and electrical characteristics of a lead-acid battery. Circle the letter preceding each correct statement.

   a. Each cell of a battery contains positive plates of lead peroxide, negative plates of spongy lead and electrolyte

   b. Each plate of a lead-acid battery cell consists of a framework called a grid, made of lead antimony, to which the active material is attached

   c. The positive and negative plates are assembled so that each negative plate is between two positive plates

   d. Between the plates are porous separators which keep the positive and negative plates from touching each other and shorting out the cell

   e. A lead-acid cell contains positive plates coated with lead peroxide; negative plates made of lead; and a liquid electrolyte, consisting of sulphuric acid and water

   f. When a cell is being charged, lead sulfate is removed only from the negative plates

   g. The open-circuit voltage of a lead-acid battery is 2.70 volts per cell when the electrolyte has a specific gravity of 1.265

   h. The electrolyte of a fully charged battery will have a specific gravity of between 1.275 and 1.300 with an electrolyte temperature of 80°F

   i. One ampere-hour of capacity is the amount of electricity that is put into or taken from a battery when a current of one ampere flows for one hour

4. Using the following example and Charts I and II, determine the state of charge of a lead-acid battery. Circle the letter before the correct answer.

A lead-acid battery's electrolyte was checked with a hydrometer and found to have a specific gravity of 1.277. The battery electrolyte temperature was determined to be to 0°F. What is the state of charge?

a. Fully charged

b. 75 percent charged

c. 50 percent charged

d. 25 percent charged

CHART I

Battery Hydrometer Readings

Readings	Battery Condition
1.275 - 1.300 Specific Gravity	100% Charged
1.250 - 1.274 Specific Gravity	75% Charged
1.220 - 1.249 Specific Gravity	50% Charged
1.190 - 1.219 Specific Gravity	25% Charged

CHART II

(A) Electrolyte Temperature		Correction Points Add or Subtract
°C	°F	
60	140	+24
55	130	+20
49	120	+16
43	110	+12
38	100	+ 8
33	90	+ 4
27	80	0
23	70	- 4
15	60	- 8
10	50	-12
5	40	-16
- 2	30	-20
- 7	20	-24
-13	10	-28
-18	0	-32
-23	-10	-36
-28	-20	-40
-35	-30	-44

5. State the two properties used to rate the design performance of aircraft batteries.

   a. ____

   b. ____

6. State the characteristics of a properly maintained lead-acid battery.

   a. ____

   b. ____

   c. ____

7. Distinguish between characteristics of voltage and current relative to the constant-current and constant-voltage charging systems. Write "CC" in the blanks preceding constant-current characteristics and "CV" in the blanks preceding constant-voltage characteristics.

   _____a. Current remains constant throughout the charging process

   _____b. Current rate is usually no more than 7 percent of the ampere-hour rating of the battery

   _____c. A discharged battery will allow a large amount of current to flow into it when the charge is first begun, but as the charge continues the current will decrease

   _____d. Requires a longer time to fully charge a battery and toward the end of the process, presents the danger of overcharging

   _____e. During the charging process the amount of current automatically tapers off, reaching a value of approximately one ampere when the battery is fully charged

8. Select true statements related to safety precautions used during lead-acid battery charging. Circle the letter before each true statement.

   a. Make sure lead-acid batteries are sealed during charging to avoid the escape of hydrogen gas

   b. Separate tools and equipment for lead-acid batteries from nickel-cadmium batteries

   c. Store tools and metal parts with batteries to avoid contamination

   d. Service a charged battery with distilled water only, never with electrolyte

   e. Avoid exposure to corrosive or toxic chemicals and explosive gases

   f. Make sure any battery found hot and overcharged is grounded across its terminals immediately to discharge electrical pressure

THEORY TEST

9. Inspect and service a lead-acid battery.

   (NOTE: Test question 9 is a project guide. It is an important part of this test. If it has not been completed, check with your instructor.)

10. Select true statements related to the internal construction and electrical characteristics of a nickel-cadmium battery. Circle the letter preceding each correct statement.

    a. The positive plates are made of powdered nickel called plaque fused or sintered to a nickel wire-mesh screen

    b. The nickel-cadmium battery consists of positive and negative plates, separators, electrolyte, cell vent and cell container

    c. The electrolyte used in nickel-cadmium batteries is a 40 percent solution of potassium hydroxide in distilled water

    d. When a charging current is applied to a nickel-cadmium battery, the negative plates lose oxygen and begin forming metallic cadmium

    e. Gassing occurs in the cells as the electrolyte is decomposed by electrolysis

    f. As electrons flow from the positive terminal of the nickel-cadmium battery, oxygen is driven from the negative plate and is recovered by the positive plate

    g. The specific gravity of the electrolyte used in nickel-cadmium batteries is between 1.75 and 1.80 at 90°F

    h. The specific gravity of the electrolyte is no indication of the state of charge of the battery

11. Explain the process of deep-cycling a nickel-cadmium battery.

    ____

    ____

    ____

    ____

    ____

12. Select proper maintenance and safety procedures for servicing nickel-cadmium batteries. Circle the letter before each correct response.

    a. Use insulated lead-acid battery tools for both lead-acid and nickel-cadmium battery servicing

    b. Never wear metal jewelry when performing aircraft maintenance

    c. Avoid prolonged low discharge rates, as this can lead to temperature imbalance and thermal runaway

    d. Connect grounding straps before disconnecting dummy loads to avoid sparking

13. Inspect and service a nickel-cadmium battery.

    (NOTE: Test question 13 is a project guide. It is an important part of this test. If it has not been completed, check with your instructor.)

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ANSWERS TO THEORY TEST

1. a. 2
   b. 3
   c. 5
   d. 4
   e. 6
   f. 1
   g. 14
   h. 12
   i. 9
   j. 10
   k. 11
   l. 7
   m. 8
   n. 13
   o. 20
   p. 18
   q. 15
   r. 16
   s. 19
   t. 17
   u. 22
   v. 23
   w. 21
   x. 25
   y. 26
   z. 24
   aa. 27
   bb. 28
   cc. 29
   dd. 30
   ee. 31

2. a. 2, 3, 5
   b. 1, 4

3. a, b, d, e, h, i

4. c

5. a. Voltage
   b. Ampere-hour rating

6. a. Correct electrolyte levels
   b. Clean case and terminals
   c. Specific gravity of electrolyte indicating a full charge

7. a. CC
   b. CC
   c. CV
   d. CC
   e. CV

8. b, d, e

9. Performance skills evaluated to the satisfaction of the instructor

10. a, b, d, e, h

11. The charge in each cell must be reduced to zero and stabilized. The battery is then recharged, monitoring each cell's voltage within specific limits until full charge is reached (140 percent of amp-hour rating)

ANSWERS TO THEORY TEST

12. b, d

13. Performance skills evaluated to the satisfaction of the instructor

PRACTICAL TEST #1--Inspect and Service Lead-Acid Battery

INSTRUCTOR'S GUIDE

I. STUDENT ACTIVITY - The student will be required to service, determine the state of charge, and fully charge a lead-acid battery. The student must use the correct references and perform the required procedure within the specified tolerances and time limits using proper safety procedures.

II. PREPARATION FOR TEST

A. Select a lead-acid aircraft battery and determine its state of charge

B. Review the following evaluation form

C. Have the student provide you with the practical test guide and evaluation form from the student guide

(NOTE: For reference, a copy of the student evaluation guide has been placed in the instructor's guide.)

D. Fill out the student evaluation guide for the assigned aircraft

E. Provide the student with the battery and student evaluation guide

F. Provide the student with a selection of possible manuals, including the required manuals, to be used in this procedure

G. Provide the student with possible tools and equipment, including the required tools and equipment, to use in the procedure

H. Monitor the student's performance and record the results on the evaluation form

I. Inspect the work when completed

J. Calculate scores on evaluation form and determine student rating

K. Discuss the student's performance

L. Reteach and retest as necessary

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PRACTICAL TEST #1--Inspect and Service Lead-Acid Battery

STUDENT GUIDE

I. INTRODUCTION

There are two sources of electrical energy in an aircraft: (1) the generator, which converts mechanical energy into electrical energy and (2) the battery, which converts chemical energy into electrical energy. The storage battery is used as an auxiliary source of power when the generator is not operating. Therefore, it is necessary for you as an aviation maintenance technician to be able to competently inspect and service aircraft batteries. The lead-acid battery is the most commonly used storage battery for aircraft. For this reason it is necessary for you to demonstrate your ability to inspect and service lead-acid batteries. This practical test requires that you inspect, determine the state of charge, and service a lead-acid battery. It is necessary that you use the correct references and perform the procedure within the specified tolerances and time limits using proper safety procedures. Record all information in the blanks provided.

II. Hydrometer selected ____

III. Temperature selected ____

IV. Chart selected for correct low range tester ______________________

____

V. Battery charger selected ______________________________________

VI. Amount of time selected for charger _____________________________

VII. Overall description of the condition of the battery ________________

____

____

____

____

____

____

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PRACTICAL TEST #1--Inspect and Service a Lead-Acid Battery

EVALUATION GUIDE

Name:________________________ Date:________________________

Performance Evaluation Key

Student's performance is typical of an: Point value

A = Exceptionally competent worker = 5
E = Incompetent worker = 1

Degree of Importance Factors

To be multiplied by performance evaluation key letter value

(NOTE: All steps in this process are critical. They will be rated at a degree of importance factor of 5.)

5 = Critical
4 = Essential
3 = Important
2 = Necessary
1 = Least important

(EVALUATOR NOTE: Circle the appropriate letters earned and make the necessary calculations to determine the score.)

Item No.		Process (225 pts. possible) A	E				
1.	Checked battery electrolyte	5	1	x	5	=	______
2.	Selected correct hydrometer	5	1	x	5	=	______
3.	Selected correct temperature	5	1	x	5	=	______
4.	Selected correct chart for low range tester	5	1	x	5	=	______
5.	Cleaned battery	5	1	x	5	=	______
6.	Selected correct battery charger	5	1	x	5	=	______

PRACTICAL TEST #1

Item No.		A	E			
7.	Selected correct amount of time for charger	5	1	x	5	= ______
8.	Worked safely	5	1	x	5	= ______
9.	Selected and used proper safety equipment	5	1	x	5	= ______

Total process score = ______

Item No.		Product (75 pts. possible)				
		A	E			
10.	Determined specific gravity within acceptable tolerance	5	1	x	5	= ______
11.	Determined temperature of specific gravity within acceptable tolerance	5	1	x	5	= ______
12.	Used time economically	5	1	x	5	= ______

Total product score = ______

Total process score ______

Total product score + ______

Total test score = ______

(NOTE: You must receive an "A" rating on item numbers 8 and 9. If those items are passed, then the acceptable passing score is 255.)

PRACTICAL TEST #2--Inspect and Service Nickel-Cadmium Battery

INSTRUCTOR'S GUIDE

I. STUDENT ACTIVITY: The student will be required to deep-cycle a nickel-cadmium battery and return it to full state of charge. The student must use the correct references and perform the required procedure within the specified tolerances and time limits using proper safety procedures.

II. PREPARATION FOR TEST:

A. Select a nickel-cadmium aircraft battery

B. Review the following evaluation form

C. Have the student provide you with the practical test guide and evaluation form from the student guide

(NOTE: For reference, a copy of the student evaluation guide has been placed in the instructor's guide.)

D. Fill out the student evaluation guide for the assigned aircraft

E. Provide the student with the battery and student evaluation guide

F. Provide the student with a selection of possible manuals, including the required manuals, to be used in this procedure

G. Provide the student with possible tools and equipment, including the required tools and equipment, to use in the procedure

H. Monitor the student's performance and record the results on the evaluation form

I. Inspect the work when completed

J. Calculate scores on evaluation form and determine student rating

K. Discuss the student's performance

L. Reteach and retest as necessary

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PRACTICAL TEST #2--Inspect and Service Nickel-Cadmium Battery

STUDENT GUIDE

I. Turbine engines, with their demand for extremely high current for starting, have encouraged the development of an alkaline battery for aircraft use. There are significant differences in servicing methods required for nickel-cadmium batteries and lead-acid batteries. Therefore, it is necessary for an aviation maintenance technician to be competent in the inspection and servicing of both types of batteries. This practical test will give you the opportunity to demonstrate your competency in inspecting and servicing nickel-cadmium batteries. You will be required to deep-cycle a nickel-cadmium battery and return it to full state of charge. It will be necessary for you to use the correct references and to perform the required procedure within the specified tolerances and time limits using proper safety procedures. Record all information in the spaces provided.

II. Cell leakage reading ____

III. Battery charger selected ____

IV. Battery cables selected ____

V. Battery charger setting selected ____

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PRACTICAL TEST #2--Inspect and Service Nickel-Cadmium Battery

EVALUATION GUIDE

Name:______________________________ Date:__________________________

Performance Evaluation Key

Student's performance is typical of an:		Point value
A = Exceptionally competent worker	=	5
E = Incompetent worker	=	1

Degree of Importance Factors

To be multiplied by performance evaluation key letter value

(NOTE: All steps in this process are critical. They will be rated at a degree of importance factor of 5.)

5 = Critical
4 = Essential
3 = Important
2 = Necessary
1 = Least important

(EVALUATOR NOTE: Circle the appropriate letters earned and make the necessary calculations to determine the score.)

Item No.		Process (200 pts. possible)					
		A	E				
1.	Cleaned battery	5	1	x	5	=	_______
2.	Checked for cell leakage	5	1	x	5	=	_______
3.	Selected correct battery charger	5	1	x	5	=	_______
4.	Selected correct cables for battery	5	1	x	5	=	_______
5.	Selected correct setting on battery charger	5	1	x	5	=	_______
6.	Followed manufacturer's recommended procedures to prevent thermal runaway	5	1	x	5	=	_______

PRACTICAL TEST #2

Item No.		A	E				
7.	Worked safely	5	1	x	5	=	______
8.	Selected and used proper safety equipment	5	1	x	5	=	______

Total process score = ______

Item No.		Product (50 pts. possible)					
		A	E				
9.	Determined cell voltage within manufacturer's specifications	5	1	x	5	=	______
10.	Used time economically	5	1	x	5	=	______

Total product score = ______

Total process score ______

Total product score + ______

Total test score = ______

(NOTE: You must receive an "A" rating on item numbers 6, 7, and 8. If those items are passed, then the acceptable passing score is 212.)